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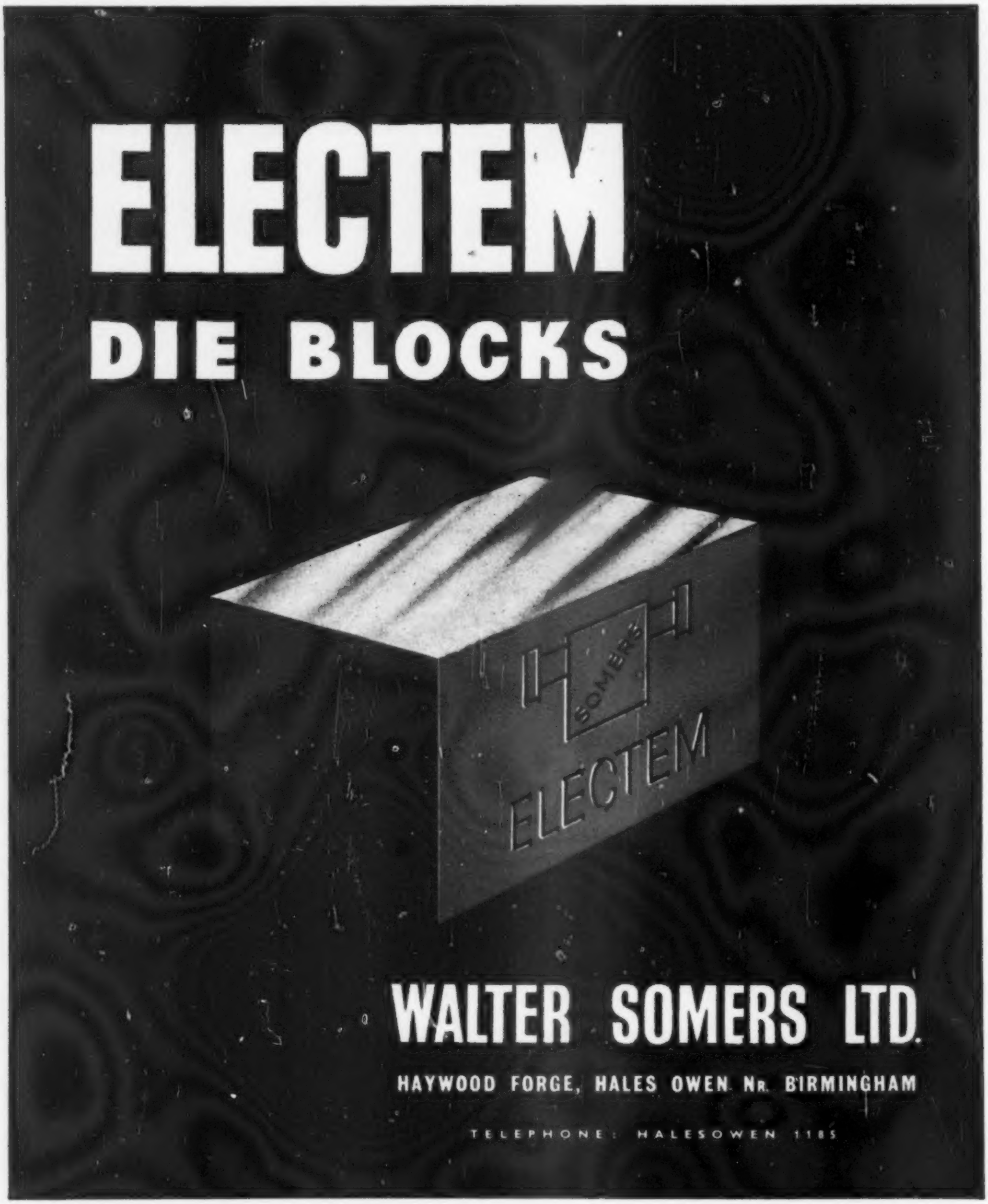
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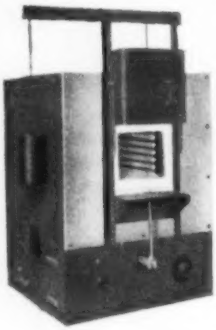

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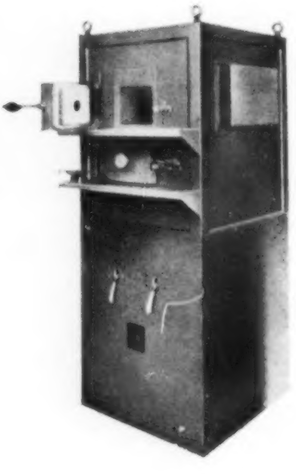

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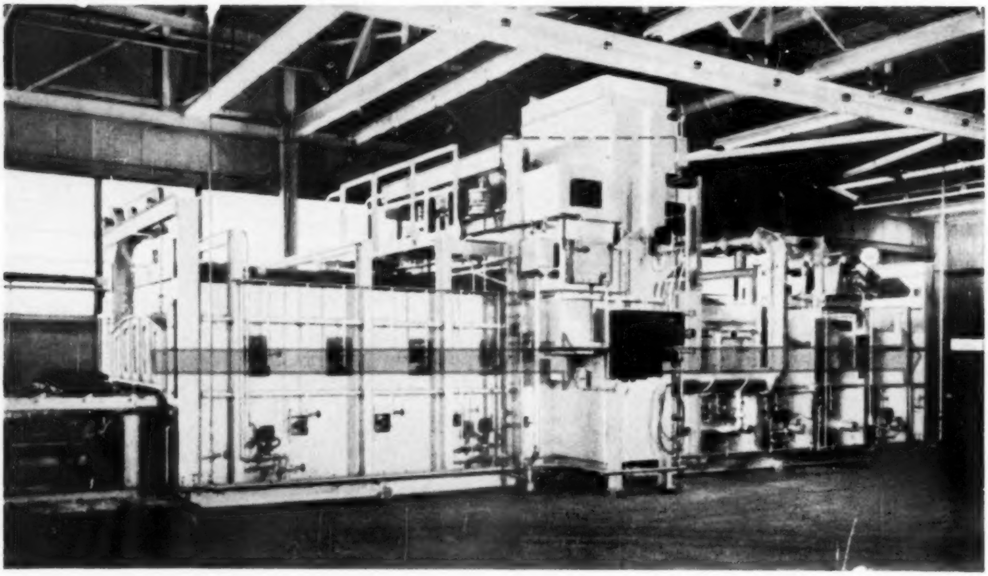

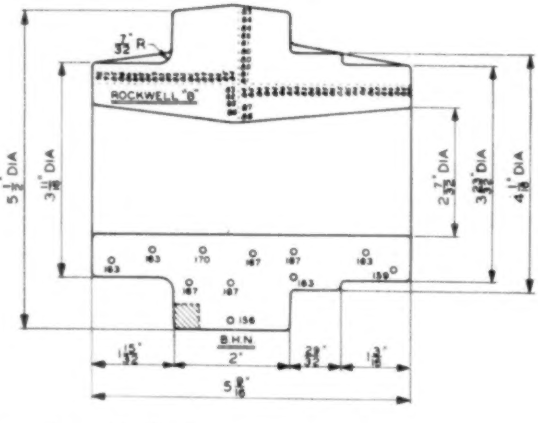

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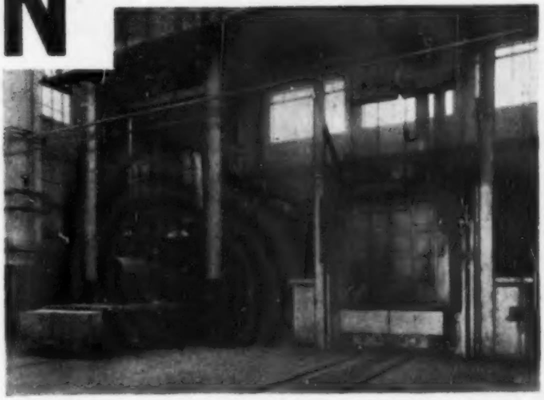

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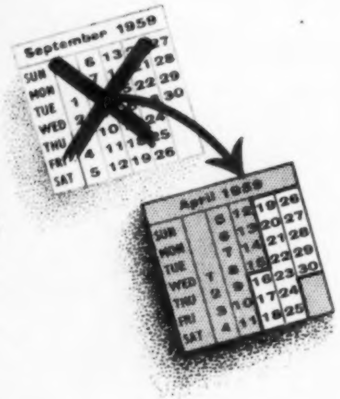

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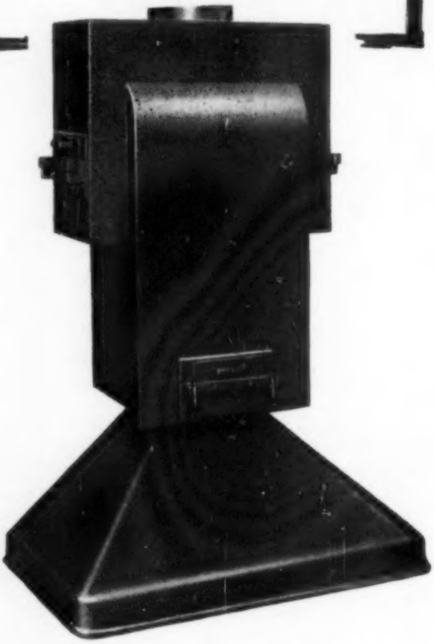

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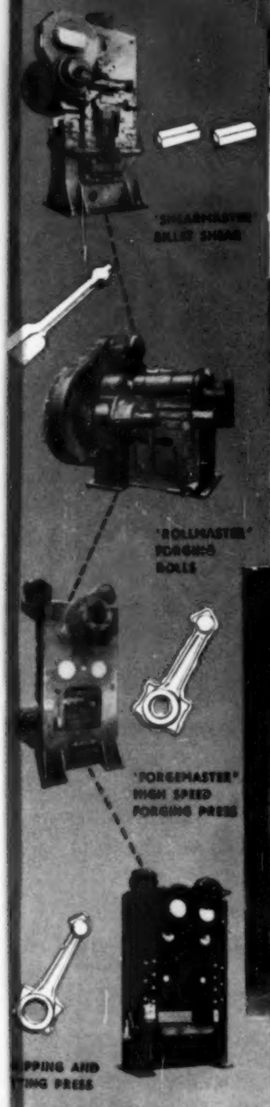

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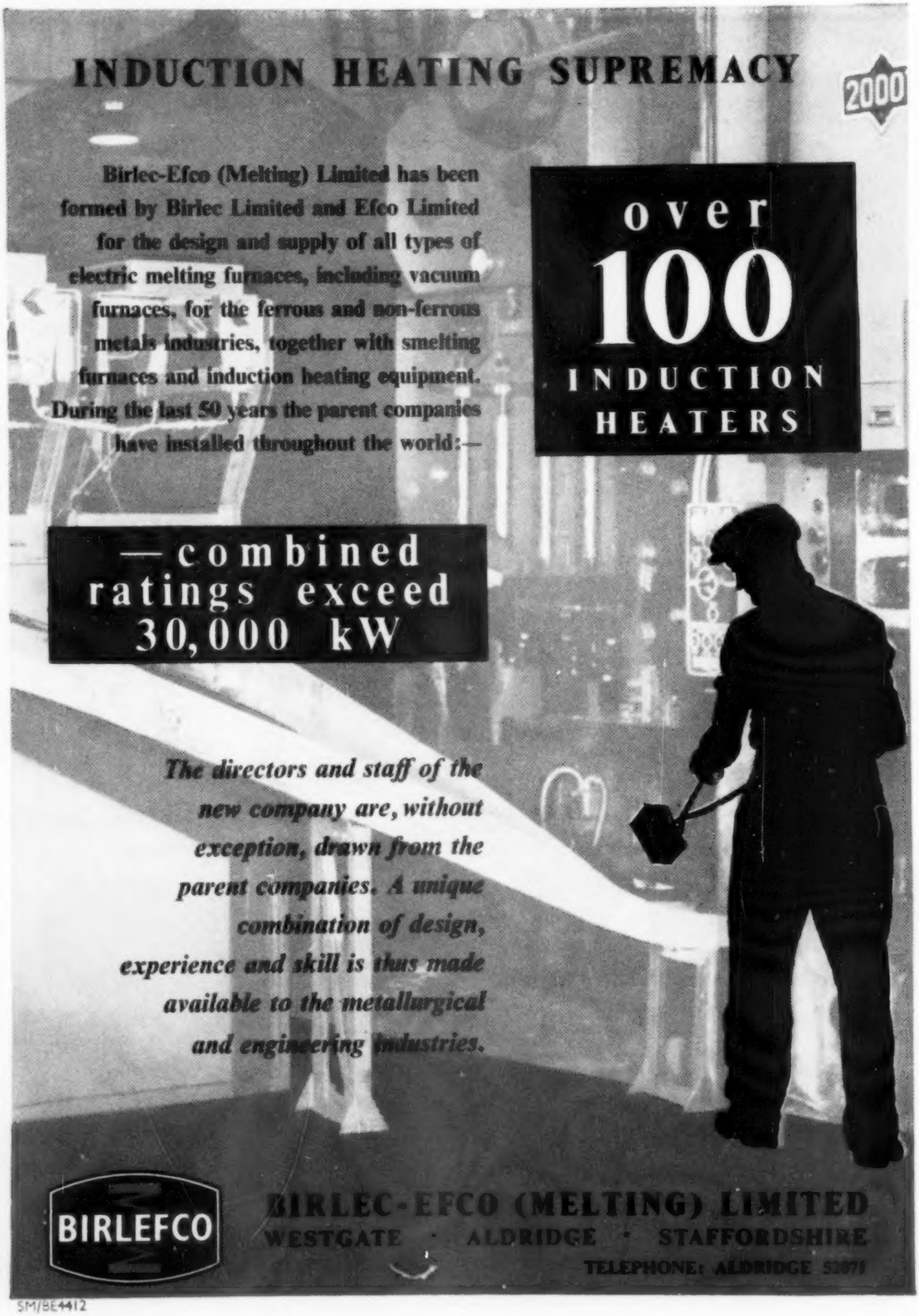
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CONTENTS

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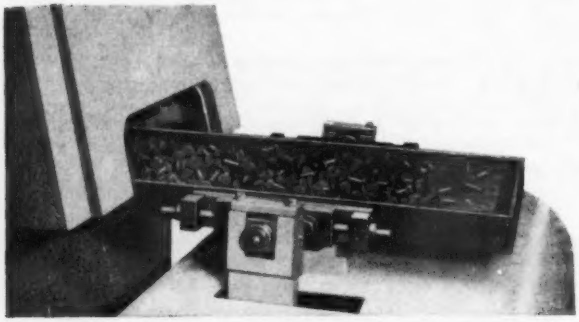

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Getting it straight

WE publish an article this month which raises once again the question of the relationship between scientific research and industrial development. In his opening address given to the Autumn Meeting of Société Française de Métallurgie held in Paris in October, Professor Antonio Scortecci, who may be said to have 'fathered' the Institutio Siderurgico Finsider in Italy (roughly speaking an Italian counterpart of BISRA), spoke at some length on the technical and human problems which have confronted him from time to time. While Italy is not one of the major steelmaking countries of Europe, it is to be noted that after she regained her annual pre-war output of about 2½ million tons in 1950 her production has risen at a remarkably high rate, reaching nearly 6 million tons in 1956. This represents an average rate of increase of 14% per annum, rather more than double that achieved in Britain over the same period, and we are glad of this opportunity to reproduce some of the Professor's main points. One of the most significant of the Professor's remarks is, we think, his admission that, contrary to what he had previously believed, he found that the human element was the predominant factor in determining the level and efficiency of production. This is clearly of vital importance, and it underlines in particular the part which 'management' in all its aspects plays in industry. Bad management, failure in 'human engineering,' can undo completely whatever good is done by the employment of scientific and technically-trained personnel.

A second point made by Professor Scortecci, which is very closely tied up with the human and management questions, is the fact that intelligent foremen can and do play such a very important role in furthering industrial development. He quotes the instance of ramming dolomite dry without tar as a binder (the 'Crespi' lining) and ramming raw silica to form the gas ports of open-hearth furnaces. These are excellent examples of 'development' steps which did not wait upon 'research' before they were taken. The sloping back-wall of the open-hearth furnace, now almost universal, is a development of the same kind; Naismith, who invented it, was a foreman-bricklayer from America. These examples are well known; it is our belief that there are hundreds of others which may in themselves be very modest and never see the light of publication or patenting, but which taken together may amount to major advances in technique. It is the mark of good management that this potentially valuable source of new ideas and new manufacturing methods is kept flowing, but unfortunately there is reason to believe that all too often in Britain in the past few years it has been dammed by the hopeless confusion of thought surrounding the whole subject of research and development, by the failure to distinguish between the different kinds of development, and by the almost obsessional devotion paid to so-called 'fundamental research.'

There are broadly two kinds of development, PRODUCT development and PROCESS development, the former concerned with the emergence of some new saleable product such as a synthetic fibre or a high-tensile steel, the latter concerned with new and better methods of producing something which in general terms is already in existence. For example, perfecting a method of forging a crankshaft with fewer blows, greater accuracy and smoother finish is essentially process development. From a practical point of view, the important difference between the two is that whereas product development can nearly always be carried out to successful conclusion in the laboratory, it is only in cases where the productive operation is either normally on a small scale *or is capable of being ruthlessly scaled down* that the research laboratory can be of any use to the process developer.

A good example of the confusion of thought which can arise from failure to get these facts straight and from the deeply-rooted idea that development can only arise from scientific 'research,' is provided in the latest issue of *Steel Review*, the quarterly publication of the British Iron and Steel Federation, in which Mr. J. Stubbs Walker contributes an article entitled 'Research—life blood of the steel industry.' Mr. Walker first deals with such items of product development as new high-tensile steels, 'Fortiweld' and boron-bearing steels which have come from the research laboratories of United Steel Companies, Hadfields and others, and then goes on to consider improvements in productive technique, such as the ironmaking from 100% sinter burdens at Appleby Frodingham. In this connection he writes: 'When looking at steel research the difficulty frequently arises of deciding where the dividing line lies between research and production.' Precisely, for the plain fact is that in many of the most successful examples of process development which have appeared in the last few years there has been *no* division between 'research' and 'production' *for the new method has been successfully developed as a commercially-working process from the start.*

The kind of tergiversation into which Mr. Walker is forced by his rigid conception of the roles of research and development is illustrated by his remarks on new steelmaking processes. 'The use of oxygen and oxygen steam processes in steelmaking has reached a stage of practical operation, but as a comparatively new process it is still a subject of intensive research and development.' Presumably what we are intended to gather from this is that British technicians are hard at work perfecting or improving mixed-blast and LD converters prior to their introduction into the British steel industry. The truth (upon which Mr. Walker does not enlarge) is that oxygen steelmaking processes in one form or another have been in full commercial operation on the Continent for nearly ten years, largely because the continental steelmakers didn't waste time and money 'doing' research on them first; instead (like those admirable foremen Crespi and Naismith), they went ahead with large-scale development work almost at once. New steelmaking processes can't be developed in the research laboratory, the risk has to be taken on the shop floor, and now these new processes can only be used in this country after the payment of patent royalties.

The same story comes out from Mr. Walker's remarks on steelworks' cranes: 'Continental manufacturers have introduced cranes of much lighter construction and consequently cheaper.' Why, because their research laboratories and engineers were superior? No, because they went ahead with developing full-scale prototypes much earlier.

However, the picture is not all so black. The automatic forge in BISRA laboratories is a successful piece of process development; but, be it noted, this is a case where the operation can be carried out on a relatively small scale. Not everybody wants to forge a high-pressure boiler drum for a power station, gas-turbine blades are equally important!

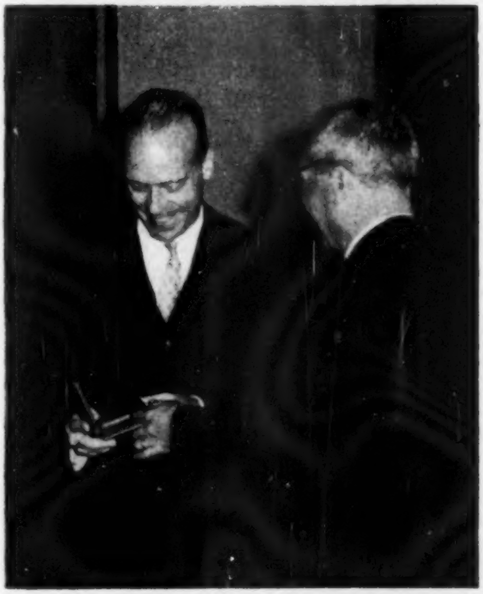
We feel very strongly that a proper appreciation of the relationship between research and development is sadly lacking in Britain, today both as regards the two different kinds of development and as regards the role of 'fundamental' research, which we have discussed previously on a number of occasions. In the latter connection another article in this issue may help to resolve or confound the argument. This is an account from Purdue University, Indiana, U.S.A., of how the pressure-temperature-composition phase diagram for the cadmium-zinc system has been elucidated by methods of applied thermodynamics. Now cadmium and zinc are separated and refined by fractional distillation ('re-fluxing'), and we shall be very interested to know whether the results found by Professor Guy and Mr. Morozumi are likely to lead to a re-design of any industrial equipment.

Technical and human aspects of research and development

Relation between 'theory' and 'practice'

PROF. ANTONIO SCORTECCI

A subject of great interest and urgent importance is the relationship of an organization devoted to research with an industry primarily devoted to production. Prof. Antonio Scortecci, director of the Instituto Siderurgico Finsider, discussed this subject in his opening address to the autumn meeting of the Société Française de Métallurgie, held last October in Paris. The following remarks are some of the points made by Prof. Scortecci in his speech, the full French text of which will eventually appear in the 'Revue de Métallurgie'



TOP *Prof. A. Scortecci delivering his address at the opening ceremony at which he was presented with the Grande Médaille le Chatelier of the Société Française de Métallurgie* BOTTOM *Mr. Charles Crussard, director of laboratories, IRSID, being presented with the Médaille Réaumur at the autumn meeting of the Société Française de Métallurgie*

In order to give a true picture of research developments in the large Finsider iron and steel group, which produces nearly two-thirds of Italian iron, it is essential to explain fully the origins of the Italian iron and steel industry, and the influence it has had on the general development of industry in that country.

It was only in 1905 that Italy joined the ranks of the iron and steel producing countries when its first coke-fired blast furnace was installed. At that time, its annual production of steel was of the order of 300,000 tons, whereas by then France was already producing 2,300,000 tons of steel a year, Germany 9,000,000, Great Britain 6,000,000, and the United States 20,000,000 tons. The gap between them was enormous, and this situation was a determining factor in Italy in the relations between science and industry.

Once national unity had been attained, the initiative in creating an Italian iron and steel industry was taken by financial undertakings, who, without any qualified technical or scientific support, purchased from abroad the necessary technological experience along with the plants.

Investigations into the metallurgy of metals of low melting points, where it was possible to carry out experiments with modest means, continued to be made in the general chemical institutes, while iron and steel remained in a purely empirical stage of development, strictly limited to the works producing them. In these works, the task of the laboratories was for a long time confined to chemical analysis of materials and to mechanical acceptance tests.

Creation of the Breda Institute

However, a very important step forward was made for the whole Italian iron and steel industry when the Breda Institute was founded in 1918. The credit for this should be given to the collaboration between that far-sighted businessman and engineer, Ernesto Breda, and the highly intelligent proposer of this scheme, Professor Parravano. The value of this institute is not so much in the research results obtained, which producers were not yet ready to understand, much less to ask for, but mainly because it was a centre for the training of metallurgists, in which most of the men, who subsequently gave direct or indirect support to the establishment of liaison between science and the iron and steel industry, were trained.

It was during a period at the Breda Institute that the author began to perceive certain human aspects of his profession. The very first time the author went on to the O-H furnace he realized immediately the need to get on good terms with, and gain the confidence of, the foremen in order to learn the job: there was no other source of information. There is absolutely no doubt that, even some years after the end of the First World War, the control of the directors of an iron and steel works was in most cases confined to the administrative side, while the production side was really left in the hands of the foremen.

Importance of foremen

These foremen came almost exclusively from among the best foundrymen, who had themselves come from among the best workmen. The process of selection was very severe, since no works' management, however incompetent it might be on the metallurgical side, would have left a head foundryman in his job, still less the head steelmaker, unless he had shown that he could produce good work definitely and continuously. Their intrinsic capability was extremely high, but, owing to their lack of basic training, they could not deal with the effects of new developments in methods of working. In spite of this, these men sometimes made remarkable contributions to the industry. We can only think with regret what an effect these contributions might have had if a more intelligent community, mindful of its own interests, had helped these men of such natural talent to develop to professional status and to make their creative contribution in fields of far wider importance.

The making of melting-furnace linings of dolomite without a binder, known and used today throughout the world, was conceived and produced by a foreman. He showed that dolomite will sinter without the addition of fluxes and he showed the advantages to be derived from this in the upkeep of furnace hearths. The application of this process was done direct in the furnace, running all the risks of these trials without making any preliminary tests in the laboratory.

An exactly similar example is that of making linings in the upper parts of O-H furnaces, particularly gas ports, with rammed raw silica. This was carried out, almost without the works' engineers knowing anything about it, on the furnace actually at work by overcoming very great difficulties and with the constant worry of causing serious trouble in production.

Obviously such men could not stand passively by when science came into their works. They made quite plain to the directors the lack of practical experience of the science experts and the damage which would be done to production if the suggestions of the scientists were adopted. Although traces can still be found in all countries of the division between science and practical experience in the iron and steel industry, there is no doubt at all that in Italy a great gulf of mutual misunderstanding has remained up to the present day.

On leaving the Breda Institute, the author went

to the old Ansaldo Steelworks as head of the laboratory where Giolitti had once worked, but which had since declined in status, owing to lack of qualified scientists, until the only work being done was by simple chemical analysis of raw materials and steel products.

Shortly afterwards, the author was appointed steel production manager. Here, initial enthusiastic efforts to apply scientific and technical knowledge immediately came up against the lack of professionally-trained colleagues, both on the production side and in the use of scientific methods in applied research work. For that reason the author's efforts were directed in two parallel directions: the professional training in iron and steel techniques of young graduates, and the development of applied research.

The human element

The first steps made in carrying out this programme showed most emphatically that the human element, which the author had hitherto considered to be secondary to technical considerations in production, was, on the contrary, predominant: results could not be obtained, even with the best will in the world and the maximum technical qualifications, without taking the human element into consideration, and, indeed, often putting it into first place.

Further experience as managing director of a works provided the opportunity of showing that it is possible—indeed, fairly simple—to get those results which everybody understands, namely, financial results, by improving basic professional knowledge, but even more so by sensible staff control; that is, by giving its due reward to merit while having regard to human demands, remembering that a man is a subject not an object, and by showing to everyone that management, applied without weakness but with justice, serves the true interests of all. But the troubles with which a works' managing director is faced are very different from those which confront a director on the central board of a large combine.

In the course of 15 years' hard work, more than 600 young people, mostly engineers, chemists, economists and other university graduates, have been brought into the works and offices of the group.

In 1946, the chairman of the Finsider group, Ing. Oscar Sinigaglia, and his eminent colleague, Ing. Guido Vignuzzi, in spite of the difficulties of that period, namely, works to be rebuilt, very low production and still lower numbers of staff, made it quite clear that future requirements would necessitate the formation of some body to deal with applied research and the training of staff for the central officers of the Finsider iron and steel group, and they decided to put the author in charge of this work. The conditions were truly difficult, but at that time there was no other possible solution.

After one year it was decided to begin research work straight away, but the problem which immediately presented itself was in what subjects was research to be done, and who was going to choose them. It was quite obvious that the works' technicians were, in principle, in the best position to decide which were the subjects of greatest practical interest by comparing production problems in the works with information obtained from outside sources. Unfortunately, the staff position at the end of the last war was a very disturbing one. Highly qualified technicians in the industry had been pitchforked into the works without any professional basic training and they had also had, in general, little opportunity of going outside the limited confines of their works to get to know the experience of others; their knowledge of technical literature, especially in foreign languages, was generally fairly restricted.

Dangers of 'detached' research

Furthermore, a research institute, detached from a works as this one was, and where the subjects to be studied were to be chosen independently, would run the risk of spending a large part of its own activities on problems, which, even if solved, might then be considered by the engineers in the works as devoid of all practical interest, an opinion probably influenced also by a psychological factor. It is natural that men, who have given their services over many years in the works, should look with some concern on young technicians who, endowed with a more scientific and professional training, work quietly away in the same works without any routine duties but are able to get better results.

It appeared, therefore, that, in the development of applied research, the first thing to be done for long-term planning was not only to draw up a reasoned programme of the subjects to be tackled, but also to put into action the most suitable methods for improving the efficiency of the staffs in the widest sense. This was, indeed, the reason which led to the establishment, alongside the research service, of a branch for the selection and professional training of graduates. The introduction into the works of well-selected and well-trained engineers is the most important contribution towards the solution of technical and human difficulties which prevent the development of research in the works.

In the last analysis the object was to effect a synthesis between the experience of the men in the works and the scientific and technical knowledge, acquired or in course of acquisition by a group

of first-rate graduates, embarked on a career of professional research with the special purpose of establishing and then maintaining the closest collaboration between research workers and technicians in the works.

After a thorough study of the problem at highest level, followed by a most careful organizing preparation, it was possible to arrange the first meeting of all the technical people in one definite section, beginning with the blast-furnace operators.

These specialists were invited to put forward their opinions; their difficulties; their ideas which it had not been possible to develop through lack of time, or means, or of high-level decision; and, finally, their proposals. They were told that it was essential to join all forces together in an attempt to make progress in the common interest. Assurance was given that each proposal would bear the name of its proposer and that each of them would be able to follow the development of his ideas in the fullest manner. For this one special section, the making of pig-iron in the blast furnace, more than 50 proposals of subjects for research were put forward during the meeting.

Collaboration between research workers and works technicians

With a view to establishing immediate collaboration between research workers and works technicians, which was the prime object of our plans, the subjects were at once grouped according to affinity, and a working committee was set up for each group, consisting of a chairman (always a works engineer, preferably a manager), a vice-chairman (always the head of the research institute), a secretary (always an employee of the institute) and a small number of members, works engineers, and research workers concerned with the special subject of the group.

The first activity of these committees was bibliographical research, carried out almost exclusively by employees of the institute under the control of their own managers. Bibliographical matter, translated fully or in a résumé, according to its importance, was circulated as it became available to the members of the working committee and also very widely to all technical staff members who had asked for it. This information, therefore, reached all those who were interested in it, with the trouble of finding and translating it already solved. Committee secretaries then prepared and circulated syntheses of this information in the form of projects based on outside experience.

The time had now arrived to move forward to the next stage of research, that is to add the experience of the technical people to that of others, and to make a synthesis of both. All the members of the committee had received, little by little, all necessary information, and in their own language, with a combined report at the end. Each of them was therefore in a position to make a mental comparison with his own experience, without any need to improvise during meetings, as is often the case.

The considered opinions of all were thus brought to light, and projects were decided upon for future trials by tests in the works or in the laboratory, or in both. When the proposals put forward called for facilities on which a decision could be made by members of the committee, the work was put in hand at once, but if, on the contrary, the projects involved expenditure or commitments on a larger scale, the management of the Finsider Institute submitted these proposals to the responsible heads in the companies concerned, or even to the Finsider Board.

That is the brief account of the way in which the research services were begun. In addition there is now a good library containing some 15,000 volumes. Some 30 standard metallurgical works have been translated, and more than 2,000 articles from technical journals have been collected, most of which have been translated by the staff of the institute. An exchange system has also been instituted with other companies.

There is now a filing system with more than 600,000 entries. Considerable work has been done towards setting up an international specialized classification system for the iron and steel industry, together with an information service, based on the files, which is now being extended to give a more complete service on an international scale.

A laboratory workshop for making, installing and repairing equipment is already fairly well developed, this being run as a small company with its own separate accounts. This has given excellent service to the producing works, particularly by the speed with which it deals with matters, and it has also put its equipment and its staff at the disposal of the research workers at extremely low cost when compared with that of a similar department incorporated in the research division itself, of which all expenses would have had to be charged against research work.

In this way not only have considerable savings been made, but there has been put before the eyes of the research workers a concrete example of how to run a small business in an economical way.

Vacuum Metallurgy

A lecture of outstanding interest will be given at the Wolverhampton and Staffordshire College of Technology, Wolverhampton, on Tuesday, January 27, 1959, at 7 p.m., when Mr. J. A. Stohr will speak on 'Vacuum welding by electron bombardment.' Mr. Stohr, who is Chef du Service du Technologie of the French Atomic Energy Commission, is the inventor of this process and his lecture will be one of the first on this subject to be given in Great Britain.

Bright annealing

A. E. PICKLES

Bright annealing, a process to eliminate or reduce after-cleaning, can be carried out by a variety of techniques including the use of protective atmospheres or the application of vacuum conditions. Mr. Pickles, director and general sales manager, Birlec Ltd., discusses these techniques in considering the range of furnaces and other plant available for different bright-annealing requirements

THERE IS NO STANDARD DEFINITION for the term 'bright annealing,' but it broadly covers annealing, stress relieving and normalizing processes carried out without significant discoloration of the treated material. Very widely used by producers of wrought metals and metal products, the process eliminates or reduces after-cleaning; it can thus make great savings in both direct and indirect production costs and can often improve the quality of the product.

Protection from oxidation during heat treatment is usually obtained by blanketing the charge with a suitable gas atmosphere. The atmosphere gases, however, must be such as to avoid undesirable effects on the treated metal—such as sulphide staining, embrittlement, decarburization, etc.—and Table I indicates the atmosphere characteristics required for the commonly used metals to ensure bright annealing.

Another method of protecting metal from oxidation is by excluding it, as far as possible, from contact with all gases during heating—*i.e.* heating it in vacuum. Vacuum-annealing is not, as yet, widely used for production purposes since it generally involves rather more complex plant than that for annealing under atmosphere. Further, certain types of furnaces which may be loosely described as vacuum-annealing furnaces do not strictly justify this description since the free space in the charge container is, in practice, filled with the evaporated lubricants from the surface of the charge, when the original air content has been removed.

For certain processes some discoloration of the annealed material is acceptable—*e.g.* when a final cleaning operation is unavoidable or where a light oxide film can be tolerated. In such cases 'clean annealing' may be practised whereby gross oxidation of the charge is avoided but stringent precautions against slight discoloration may be unnecessary. In some cases it may be desired, in fact, to produce a uniform oxide colour film on the work by suitable control of the annealing-furnace atmosphere.

Bright annealing is commonly applied to a wide range of ferrous and non-ferrous materials in a variety of forms such as wire, strip, sheet, tube, pressings, etc. Selection of the appropriate type of furnace is determined by various factors: the form in which the material is to be handled, the annealing temperature required, work-handling methods preferred, the floor space and head-room available, etc. Table II gives a general indication of the furnace types which have been proved to be most useful for different classes of work and the type of atmosphere best suited to the respective conditions.

In the following pages the principal types of bright-annealing furnaces operating with prepared

TABLE I *Atmosphere characteristics required for bright annealing*

Material	Undesired effect	Atmosphere corrective factor
Mild steel	Oxidation	Freedom from O_2 Adequate H_2/H_2O ratio Adequate CO/CO_2 ratio
Carbon steel	Oxidation Decarburization	As for mild steel Low H_2O content High CO/CO_2 ratio Some free hydrocarbon may be desirable
Stainless steel	Oxidation Carburization	Virtually complete freedom from H_2O, CO_2, CO and other oxygen or carbon containing gases
Nickel alloys	Oxidation Sulphiding	Freedom from O_2 Freedom from sulphur compounds
Copper	Oxidation Sulphiding Embrittlement	Freedom from O_2 Freedom from sulphur compounds Low H_2 content

TABLE II *Furnace types and atmospheres for various classes of work*

Material	Form	Operation	Furnace type		Atmosphere
			Continuous	Batch	
Copper and cupro-nickel	Wire (coiled or spooled) and coiled strip	Bright anneal	Pusher-tray	Bell or pit	Burnt ammonia or lean exothermic with full sulphur purification
	Sheets	Bright anneal	Mesh-belt	—	
	Wire in strands	Bright anneal	Pull-through	—	
	Tubes in straight lengths or coils	Bright anneal	Mesh-belt or roller-hearth	—	
		Clean anneal	Roller-hearth	—	Products from direct gas firing
Brass and nickel-silver	Wire and strip in coils	Clean anneal	Pusher-tray or roller-hearth	Bell or pit	Lean exothermic or products from direct gas firing or steam
	Tubes, sheets and pressings	Clean anneal	Mesh-belt or roller-hearth	—	
	Wire in strands	Clean anneal	Pull-through	—	
Stainless steel	Strip and wire in strands	Bright anneal	Pull-through	—	Cracked ammonia or pure hydrogen
	Small pressings, etc.	Bright anneal	Mesh-belt	—	
	Straight, small-bore tubes	Bright anneal	Pull-through or mesh-belt	—	
Carbon steel	Strip and wire in coils	Bright anneal	—	Bell or pit	Dry burnt ammonia or lean exothermic stripped of CO_2 and H_2O
Mild steel	Strip and wire in coils	Bright anneal	—	Bell or pit	Rich exothermic or lean exothermic stripped of CO and H_2O
	Sheets and strip or tube in lengths	Bright anneal or normalize	Roller-hearth	—	Rich exothermic
	Pressings and components	Bright anneal or normalize	Mesh-belt or roller-hearth	—	
Electrical	Laminations, sheets or strip	Clean stress-relief	Mesh-belt or roller-hearth	Bell	Burnt ammonia or lean exothermic stripped of CO_2 and H_2O

gas atmospheres are illustrated and briefly described. Reference is made, in a separate section, to atmosphere-generating equipment, though a full discussion on the metallurgical and chemical aspects of furnace-atmosphere control is beyond the scope of this article.

Batch furnaces

(a) *Bell type*. Primarily employed for treating material in coiled form, the bell-type furnace supports the charge on a suitable base over which a gas-tight metal cover is lowered to engage suitable seals, permitting the interior to be purged with atmosphere gases. Usually, three or more such bases with covers are served by one movable heating chamber which may be lowered over each in turn, thus allowing the exposed containers to be cooled, unloaded and reloaded in rotation. This type of furnace can also be adapted for vacuum-annealing.

In most applications for this type of furnace an atmosphere-circulating fan is mounted below the charge in each base to promote rapid and uniform heat transfer during both heating and cooling cycles. The movable furnace chamber is usually electrically heated and connections are made by plug-and-socket arrangement at each station. Similar furnaces are also equipped for gas firing, usually with radiant heaters. Though the shape is commonly cylindrical, rectangular bell furnaces are also built to accommodate stacks of flat sheets or multiple stacks of coils.

A feature of the bell furnace is that the hearth is generally at a convenient loading level and can be made sufficiently robust to carry heavy charges.

All piping for atmosphere gas can be conveniently installed in a trench underneath. A disadvantage is the necessity for a crane of sufficient capacity to lift the heating chamber complete.

(b) *Pit type.* Essentially similar to bell furnaces but with the arrangement inverted, pit furnaces are sometimes preferred where they permit more convenient handling arrangements. In pit furnaces, the charge is carried on a grid suspended from the furnace cover which is sealed into the mouth of a gas-tight pot. The assembly is lowered into the furnace-heating chamber and atmosphere gas connected by flexible pipes. The pot and its contents are removed, after treatment, to a convenient station for cooling. This arrangement requires less head-room in the shop than a bell-furnace installation and a lower crane capacity.

Pit furnaces are essentially cylindrical in shape and therefore adapted mainly to coiled material. They cannot, in general, handle such heavy loads as the bell-type furnace, but are otherwise similar in performance. Circulating fans may be fitted, as in bell furnaces, but may be somewhat less efficient since the height of the load affects its distance from the fan. The seal between the pot and the furnace cover is usually made by a water-cooled flexible gasket which can be arranged to seal against either vacuum or gas atmosphere.

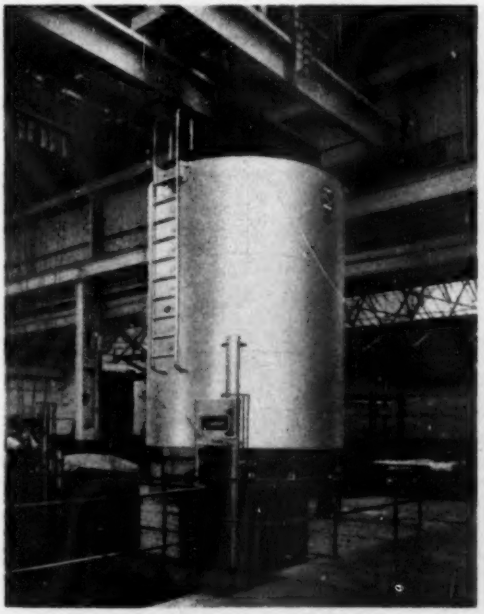
(c) *Elevator type.* Certain types of charge are conveniently loaded on to a bogie which may be moved underneath an elevated furnace chamber and then lifted into it. This method of handling has been adopted, with advantage, for annealing stacks of sheets. Traversing and lifting of the bogie are performed by power drives, and the shop crane is thus not monopolized by the handling of furnace charges.

Usually, elevator furnaces are built with a gas-tight outer casing against which the bogie base is closed by a sand seal. A controlled atmosphere is thus retained without the use of an inner gas-tight cover over the charge, though the latter arrangement can be adopted where it is desired to reduce the cooling time to a minimum.

Heating may be by electric elements or gas-fired radiant tubes and, in the absence of charge covers, atmosphere circulation is promoted by fans in the roof of the furnace. The constructional features permit heavy charges to be handled.

(d) *Horizontal furnaces.* Mainly for small-scale operations, the horizontal furnace employs a gas-tight heating chamber directly connected to a

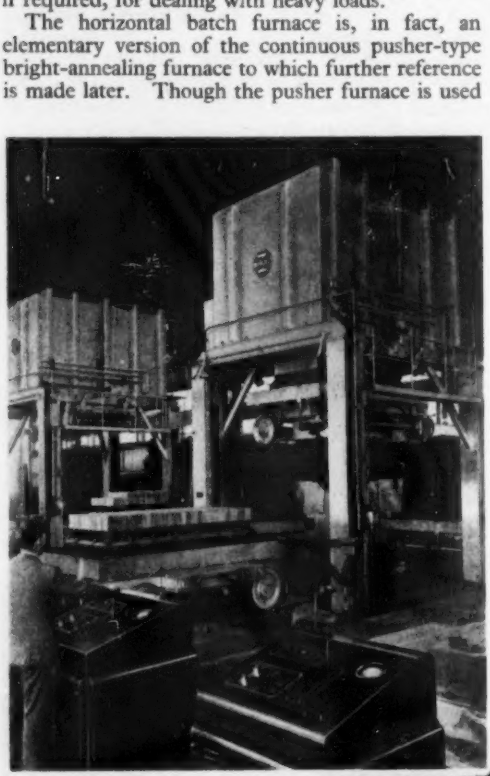
1 *Lift-off bell-type furnace for bright annealing steel wire coils, showing movable heating chamber being lowered into position*



2 *Installation of pit-type bright-annealing furnaces for silicon iron cores*

sealed cooling chamber. Work is pushed into the heating chamber and thence into the cooling chamber by hand on a suitable tray, though mechanized charge handling can be readily applied, if required, for dealing with heavy loads.

The horizontal batch furnace is, in fact, an elementary version of the continuous pusher-type bright-annealing furnace to which further reference is made later. Though the pusher furnace is used for large-scale production, the batch type is not usually considered practical beyond charge capacities of, say, 50-100 lb.



3 ABOVE *Battery of elevator furnaces showing movable hearth bogies with gas-tight covers, one bogie being raised into position*

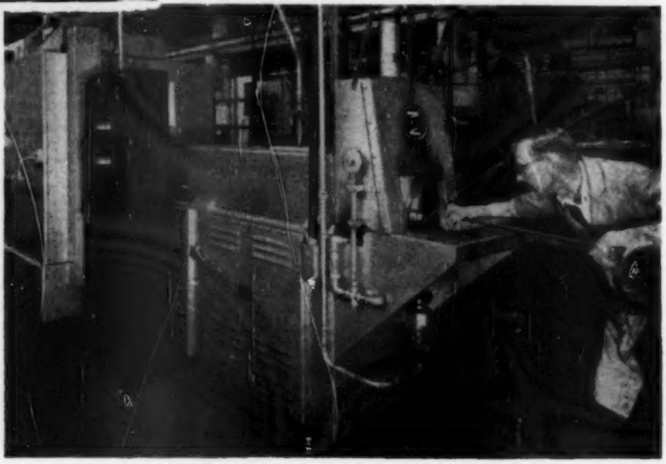
Continuous furnaces

When the material to be treated is in long lengths or in some other form which does not conveniently permit stacking, a continuous furnace is generally used. The continuous method of treatment, moreover, ensures maximum uniformity and permits quick cooling where necessary.

Atmosphere retention in continuous furnaces usually depends on keeping the entry and discharge openings as small as possible. If large end openings are unavoidable, they may be fitted with lock chambers or downward-sloping extension cowls to restrict the escape of gas.

(a) *Pull-through furnaces.* Wire and strip, in strands, may be drawn through the furnace by traction rolls or coiling gear at the discharge end; small-bore tubing may be handled similarly by attaching it to a draw-wire running through the furnace. For continuous wire annealing, each strand may pass through an individual tube purged with a protective gas, but for strip annealing the atmosphere is usually retained by the gas-tight outer casing of the furnace.

Stainless steel, however, needs the most scrupulous atmosphere purity and an internal alloy muffle is therefore generally required in furnaces for treating this material in any form. Muffle life, at the temperature required for annealing stainless steel, is limited but the equivalent production cost may still be much less than the alternative cost of cleaning the material. In the case of strip requiring a polished finish, it may be supported on a carrier strip or on rollers to prevent scratching.



4 RIGHT *Horizontal, batch-type controlled-atmosphere furnace for bright annealing and brazing*

(b) *Belt furnaces.* Probably the simplest and most versatile form of conveyor for continuous furnaces is a flexible belt woven of heat-resisting wire. Passing over drums at either end of the furnace and returning underneath the casing, such a conveyor handles a wide range of articles, including pressings, stampings, sheets, etc.

Modern heat-resisting materials and belt-weaving techniques permit such conveyors to be built for operating temperatures up to 1,150°C. Design of the belt driving and tensioning gear has an important bearing on the service life of such conveyors. The important requirement is that the point of maximum tension stress in the belt shall not occur in the region of maximum belt temperature.

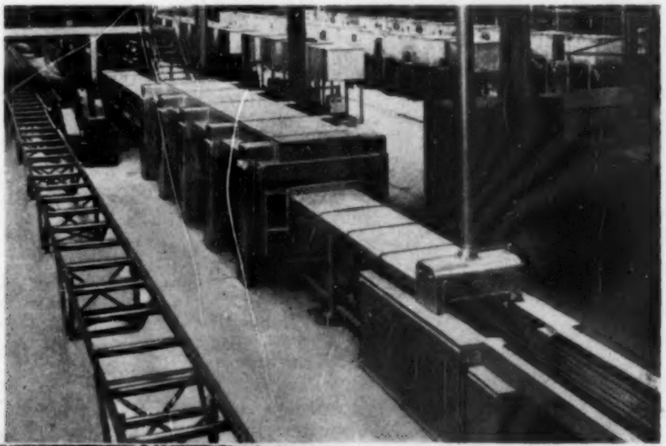
Electric heating is usually employed and a gas-tight outer casing retains the prepared atmosphere. For treating certain stainless steels, a continuous gas-tight muffle, through which the conveyor belt runs, is necessary in order to ensure maximum atmosphere purity.

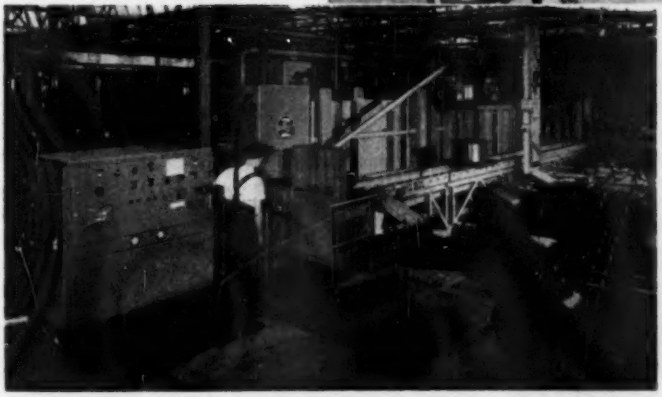
Furnaces of this type are built in widths up to 5 or 6 ft. capable of treating sheets of considerable size. Loose coils of tubing, rod, etc., can be handled conveniently on the conveyor belt, but a loading density of about 20 lb./sq. ft. of belt surface (at 900°C.) is about the limit for good belt life.

(c) *Pusher furnaces.* Heavy components which might unduly stress a wire mesh conveyor belt are often carried on heat-resisting trays which are pushed into the furnace one at a time, thereby discharging a corresponding tray at the outlet end. The trays run on rollers or skids and the pusher mechanism—usually hydraulic—may be interlocked with end doors to reduce gas loss.

The heating and cooling chambers are joined into a continuous tunnel, as in the belt-conveyor furnace, but the inlet and outlet ends may have gas-lock chambers. Where it is not convenient to

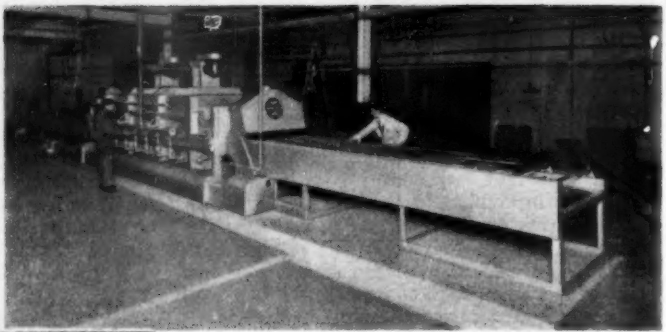
5 *Continuous bright-annealing furnace with heat-resisting wire mesh conveyor belt for copper-sheathed cable*



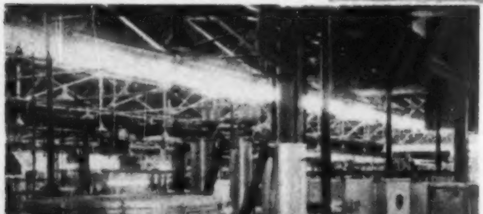


6 *Continuous pusher-type furnace for bright annealing copper wire on spools showing charging door and return track for loading and unloading work-trays*

7 RIGHT *Continuous roller-hearth clean-annealing furnace for copper tubes, heated by direct gas firing*



8 BELOW *Typical exothermic atmosphere generating plant, operating from coal gas and incorporating primary and secondary sulphur purification stages*



open and close the end doors as trays are inserted and withdrawn, the effective area of the end openings may be reduced by fitting baffles or 'bulk heads' to the trays. A gravity conveyor is generally employed to return the empty trays from the discharge end to the loading point.

Relatively heavy coils of strip or wire on spools may be conveniently treated in this type of furnace with the advantage that the work flows in an effectively continuous stream instead of in batches. Pusher furnaces may be incorporated in a factory conveyor system and generally minimize the floor space and work-handling problems which can arise from the use of batch-type furnaces which might otherwise be selected for the same class of work. Either gas or electric firing is practicable and large output capacities can be provided.

(d) *Roller-hearth furnaces.* Sheets, strips, tubes and other sections may be carried on a series of rotating rollers, thus avoiding the necessity for heating up a conveyor belt or carrier tray. Roller-hearth furnaces are therefore very extensively used in rolling mills and tube-drawing plant in capacities up to several tons per hour and for treatment involving temperatures up to 1,150°C.

The rollers in the heating chamber are, of course, of suitable heat-resisting alloy and all rollers are provided with special gas-tight end-seals. Work may be carried along the track in trays, if desired, so that this type of furnace is not confined to the treatment of straight lengths of material.

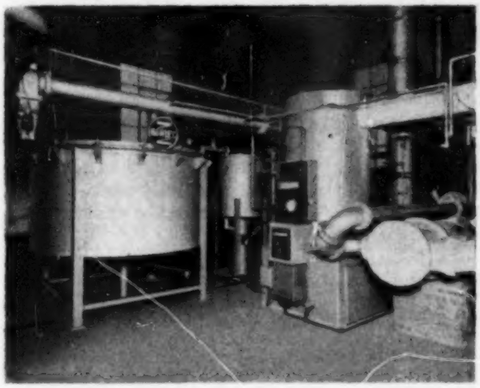
A number of gas-fired roller-hearth furnaces for annealing non-ferrous materials rely on the closely controlled combustion conditions to maintain a substantially oxygen-free atmosphere in the furnace for clean annealing. In such furnaces the heated work may be cooled, on emerging from the furnace chamber, by direct water spray since the presence of steam in the atmosphere is permissible for the materials treated. This construction is economical by eliminating the cost of a separate atmosphere generator and water-jacketed cooling chamber.

The roller conveyor can be arranged to run work quickly into the furnace, then carry it at a reduced speed—or hold it stationary—in the heating chamber, after which quick discharge can be provided. This feature gives the roller-hearth furnace great flexibility for dealing with material of varying loading density and for dealing with special annealing cycles.

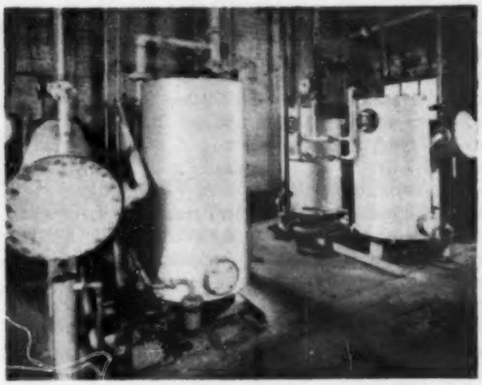
Furnace atmospheres

A full discussion on the metallurgical and chemical aspects of furnace-atmosphere control is beyond the scope of this article. It is sufficient to indicate, here, the main types of bright-annealing atmosphere and the sources from which they are obtained.

(a) *Exothermic.* The combustion products of certain fuel gases—generally town's gas, butane or propane—form the basis of most bright-annealing atmospheres. The relative proportions of nitrogen, hydrogen, carbon-monoxide, carbon-dioxide, water vapour and hydro-carbons in such gases require to



9 *Catalytic unit for removing organic sulphur from town's gas prior to combustion*



10 *Two adsorption-type atmosphere gas dryers with dual adsorber vessels alternating on continuous duty*

be controlled by regulation of the combustion conditions. Exothermic gas generators incorporate means for very simple adjustment and automatic control of the desired setting.

Gas and air, at controlled pressures, are fed through a mixing valve and pump to a burner in a refractory-lined combustion chamber where the mixture burns. The products are cooled and excess water vapour condensed out before any necessary final purification. Flow-meters indicate the gas-air ratio and the total output of the plant.

(b) *Ammonia dissociators*. For treating materials which are sensitive to the impurities in fuel gases, the dissociation products of ammonia (nitrogen and hydrogen) may form a very satisfactory furnace atmosphere. Ammonia is readily available in cylinders and may be dissociated in a 'cracker' which incorporates a heated catalyst.

The product gases may be passed directly to the furnace or may be increased considerably in volume by the controlled combustion of the hydrogen content with air, thus economizing ammonia consumption. Further economy may be obtained, in suitable cases, by circulating the gas through the furnace in a closed system to which sufficient fresh gas is added continuously to make up for leakage and to counteract any entrainment of air.

(c) *Steam atmosphere*. Certain materials which are not readily oxidized at annealing temperature by water vapour may be treated in a steam atmosphere. Where process steam is available in the factory, this can be readily piped into the furnace; otherwise, a small, low-pressure steam boiler may be installed to serve the annealing installation exclusively and several suitable units are available. As indicated in a preceding section, steam may also arise from direct cooling of the heated material with water sprays and from the combustion products of the heating system when direct gas firing is employed.

Atmosphere purification

As indicated in Table I, certain constituents of atmosphere gases may be regarded as impurities when treating certain metals, though harmless in other cases. Such impurities, according to circumstances, may be sulphur compounds, water vapour, carbon-dioxide, hydrogen or ammonia, and atmosphere plants must include appropriate equipment, as required, to remove the constituents.

(a) *Sulphur*. Town's gas contains appreciable quantities of sulphur, in various forms. Hydrogen sulphide is easily removed from the combustion products by passing them through a bed of iron oxide; sulphur-dioxide is eliminated by scrubbing with an alkaline solution.

Removal of organic sulphur from the raw gas before combustion may be necessary in certain cases and is carried out by passing the gas over a heated catalyst, followed by a scrubber. This treatment is usually necessary only when the initial sulphur content of the gas is high or where maximum freedom from sulphur in the furnace atmosphere is essential.

(b) *Carbon-dioxide*. Limitation or removal of the carbon-dioxide content of the atmosphere gas may be desirable to prevent decarburization of steel during treatment. For such requirements, a fuel-gas combustion chamber may be followed by a scrubbing tower using an amine solution which is continuously regenerated. This type of plant can produce an atmosphere of virtually pure nitrogen which is suitable for many bright-annealing operations.

An alternative method of carbon-dioxide removal is by adsorption in a tower containing molecular sieves—a highly porous, granular material. The adsorbed gas can be driven off by heating the material and it is therefore usual to employ twin adsorber towers so that one can be 'reactivated' in this way while the other is in use.

(c) *Water vapour*. Combustion of hydrogen and hydro-carbons produces water vapour which may be detrimental to some heat-treatment processes. Adsorption dryers are standardized units for removing water vapour and are readily incorporated in atmosphere plant when required. Moisture adsorbers are generally similar to the carbon-dioxide adsorbers described above. The adsorbent material is regenerated *in situ* and retains its high efficiency for years.

(d) *Hydrogen and oxygen*. The risk of hydrogen embrittlement in certain materials can be countered by adjusting the ratio of gas to air in the atmosphere generator combustion chamber so as to burn the hydrogen nearly completely. The elimination of free oxygen or undissociated hydro-carbons in the furnace atmosphere is similarly a matter of accurate control of combustion conditions. Accurate mixture control is, therefore, an important feature of atmosphere generators.

Where the least trace of hydrogen or oxygen must be removed, the gas mixture may be passed over a heated platinum catalyst. For hydrogen removal, a small quantity of oxygen is added which reacts, in the presence of the catalyst, with the hydrogen to form readily removable water vapour. Similarly, oxygen removal requires a small addition of hydrogen.

(e) *Ammonia*. Furnace atmospheres generated from ammonia may contain small traces of this gas which can be detrimental to certain materials. Adsorption plant of the type used for removing water vapour can be arranged to remove traces of ammonia with similar efficiency.

Conclusion

It has been shown that bright or clean annealing is now regularly employed in the production of both ferrous and non-ferrous sheet, strip, wire, tubes, etc., and in the fabrication of components from these materials. There is a variety of techniques available, including the use of protective atmospheres and, on the other hand, the elimination of all gases by the application of vacuum. In certain cases two methods may be combined—*e.g.* the initial removal of air and other deleterious gases by vacuum followed by the admission of a protective atmosphere of controlled composition during heating and cooling.

For all these purposes there is a wide range of furnace types and a number of atmosphere-generating plants. The type of furnace can be selected according to the form of the material and the production requirements, while the atmosphere-generating plant must be selected to provide the requisite chemical conditions for the material in question and to use the most economically available source for the required gases. For almost any normal industrial annealing or related process, there is a range of appropriate, fully-proved plant in each category, from which to make the selection.

Forging difficult materials

WITH THE INTRODUCTION of newer metals, such as titanium, into the aircraft, chemical and nuclear fields, it became necessary to devise methods of working them which took account of their peculiar properties. One of the first companies to undertake the forging of titanium when this metal was newly produced in this country was Daniel Doncaster & Sons Ltd. of Sheffield, and much of the early experimental work in forging this metal was entrusted to them.

The intricate procedures and special skills needed for the manipulation of such difficult materials could be developed only from a background of experience in forging and drop forging the more highly developed alloy and complex steels. Doncasters were able to bring their experience of the properties of difficult steels to bear upon the newer metals, and are now successfully forging on a production basis such metals as titanium, Nimonic, zirconium, aluminium bronze, heat-resisting alloys, high permeability iron, etc.

To assist firms in industries now considering the application of the newer metals into their own particular products, Doncasters have now issued an illustrated brochure; in this they also offer their experience and resources in both the design and production of components which may benefit from a new specification. Experimental work is being carried out and such work is regarded as fundamental.

Another section of the booklet covers Doncaster's activities in producing precision forged blades for compressor blades and turbine blades for gas and high-temperature steam turbines, to high standards of dimensional accuracy, surface finish and control of metallurgical structure. Also given are short descriptions of the facilities for producing hardened forged steel rolls for cold rolling and of powder metallurgy.

Copies of the brochure, 'The manipulation of difficult wrought materials,' are obtainable on request from the Publications Dept., Daniel Doncaster & Sons Ltd., Penistone Road, Sheffield.

Corrosion exhibition

The Corrosion Group of the Society of Chemical Industry is once again organizing an exhibition relating to prevention of metallic corrosion. It will be held at the Battersea College of Technology, Battersea Park Road, London, S.W.11, on January 22 and 23, 1959. The main theme of the exhibition is the apparatus and techniques used for research and for control of anti-corrosion processes, but recent developments in other fields will also be shown.

On the 22nd the exhibition will be open, from 6.30 p.m., only to members and their friends attending the Group's annual conversazione and tickets will be required. On the 23rd the exhibition will be open to all without tickets from 9.30 a.m. to 3.30 p.m.

Problems of brittle fracture

H. HARRIS B.Sc., Ph.D.

In his presidential address to the West of Scotland Iron and Steel Institute, last October, Dr. H. Harris, of Babcock & Wilcox Ltd., discussed the present state of knowledge regarding the occurrence of brittle fracture with particular reference to the construction of pressure vessels. While there are still large gaps in our understanding, Dr. Harris suggests that with good design and workmanship there is no need to fear brittle fracture in the pressure vessels of atomic power stations

OPINIONS MAY VARY concerning what the problem of brittle fracture really is, so that it is preferable to have as clearly in mind as possible the problem as seen by the manufacturer and user of pressure vessels. Engineers are concerned about the fact that important welded structures have failed by the initiation and rapid propagation of fractures *at low applied stresses*. In such instances the fractures have been of a brittle character even though the steel would have been expected by conventional standards to have behaved in a ductile manner. The real problem was not that the steel failed in a brittle manner, but that the failures were under conditions of applied stress when a failure even of small dimensions was not expected and certainly catastrophic collapse or rupture was not even dreamt of. Such failures have occurred in a ship lying calmly at its berth and in a storage tank being filled with water prior to hydrostatic test. This behaviour, of particular significance to the merchant navies during the late war, was sufficiently frequent and alarming that considerable efforts have been made to investigate the fundamental facts. In spite of these efforts, which are of international scope, the problem is by no means fully understood.

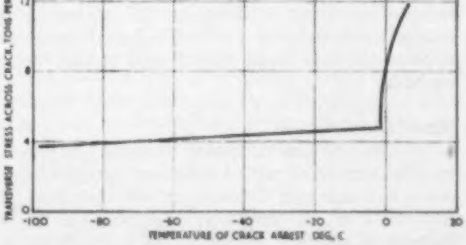
Enough research has, however, been carried out to lead to a reasonable understanding of the problem and to form the basis for an intelligent appreciation of what can and what should not be done in the design, manufacture and use of pressure vessels.

Work of Robertson and Wells

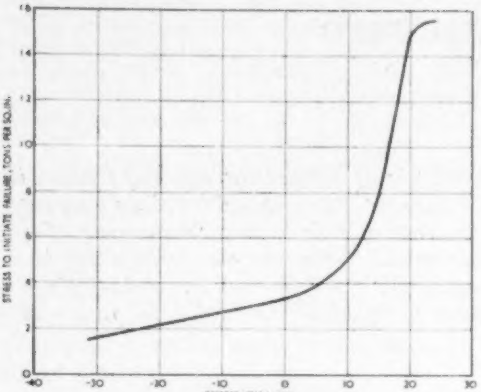
The purpose of this address is not to deal in a chronological order with the work that has been published, but rather to take the present status and to show that an enlightened outlook can now be achieved. We may, therefore, begin with a description of two major contributions that have originated in the British Isles. In the first place there is the work of Robertson at the Naval Construction Research Establishment at Rosyth. Robertson has shown that when a crack is initiated in a sample of steel held under a constant tensile stress but with a temperature gradient so chosen that the crack is initiated at a low temperature, the crack is arrested at some higher temperature, called the crack arrest temperature.

It is perhaps somewhat erroneous to define this temperature as the point where the crack stops. Robertson actually uses the temperature where the crack begins to show the change from cleavage to shear. This temperature is dependent upon the stress applied, so that in plotting this dependency we achieve a Robertson curve of the type shown in fig. 1. From this figure it will be seen that for the particular steel there is a transition temperature of the order of 0°C. above which the crack will not propagate at low stress levels but below which a crack, once initiated, will continue to travel even though the applied stress is only of the order of 4 tons/sq. in.

It will be appreciated how the engineer and the metallurgist welcomed such a clear exposition of



1 *Robertson test results*



2 *Wide-plate test results for mild steel*

one facet of the brittle fracture problem. The Robertson curve, however, is not all-sufficient. The experiment is artificial in that the method of crack initiation is quite removed from behaviours in practice; the data relates primarily to the propagation of an initiated crack.

Following this important work at the Naval Construction Research Establishment, Wells and his collaborators at the Abington laboratories of the British Welding Research Association were exploring a method of test much more representative of actual happenings. In the work at BWRA welded test plates 1 in. in thickness and 3 ft. in width were made with artificial defects in the weld. The defect took the form of a fine saw-cut extending a very restricted distance into the parent metal. The welded plate was cooled to a pre-selected temperature and then stressed uniformly in the direction of the weld. Using an ordinary mild steel, it was found that a relationship of the type shown in fig. 2 existed between the temperature and the stress necessary, in this instance, to initiate failure. Again it will be seen that some type of transition behaviour exists.

From a consideration of these experiments it will be appreciated that conditions very similar to actual failures are being produced in the laboratory and that as a consequence a tool of supreme importance appears to have been forged and should be exploited.

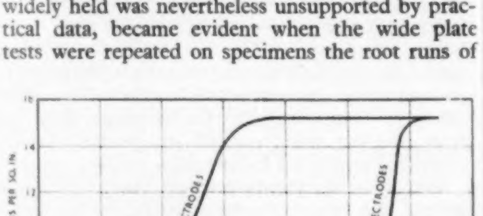
Residual stresses

In view of the necessity to make progress as rapidly as possible with the limited resources available, the research laboratories of Colvilles Ltd. undertook an investigation to determine the influence of residual stresses. As a result of this series of tests it was shown by Kennedy that the presence of the residual stresses consequent on the welding operation was necessary if fracture at stresses lower than the yield point were to be initiated. This was, in fact, an achievement of real merit and significance. Whatever opinion a person might have harboured privately, there was a tremendous body of informed opinion that held to the belief that residual stresses had played no part in the brittle-fracture failures. Now at last that opinion is shattered, and it is now recognized that stress relief has a decisive effect on whether a structure will or will not fail in a brittle manner at low levels of applied stress.

It might appear that at this point those interested in pressure vessels could afford to sit back and say that so far as they were concerned the problem was settled—apply stress relief and the fear of brittle fracture vanishes. However much truth there would be in such an attitude it is not the complete story; the problem of brittle fractures during construction and in vessels that cannot be stress-relieved would remain.

It happened that fig. 2 had been obtained from specimens which had been welded using rutile-coated electrodes. The choice of such electrodes was not altogether fortuitous as they were at that time being widely used for the site construction of storage tanks on account of the facility with which they could be used by the welders. It had also been thought that because of the good notch impact properties, they would be a reliable choice when the possibility of brittle fracture was taken into account.

A realization of how misleading conclusions can be when made from some hypothesis, which though widely held was nevertheless unsupported by practical data, became evident when the wide plate tests were repeated on specimens the root runs of



3 *Wide-plate test results for mild steel (according to Wells)*

which were deposited using low-hydrogen electrodes. Fig. 3 shows the two curves, and a significant difference is clearly to be seen.

It has been stated that these experiments by Wells at the BWRA laboratories reproduce actual conditions that are encountered in practice. An unbiased assessment will, it is believed, allow that the actual conditions of the test are what one could expect in a construction involving butt welds. The only proviso would possibly be that the severity of the initiating defect in Wells' test specimens is much more severe than would be found in even reasonably good industrial practice. Also, the results of the tests undeniably reproduce what has been found in brittle-fracture failures, namely, fractures in welded construction initiated at low applied loads. It is therefore difficult to believe that these experiments cannot be translated directly into practical terms.

Arising from this is the conclusion that if a structure, as such, has a transition temperature and if this transition temperature, as shown by the Wells data, has real significance, it cannot at present be derived on the basis of the conventional laboratory determinations of notch impact properties of the materials, for example, plate or weld metals, employed in the construction.

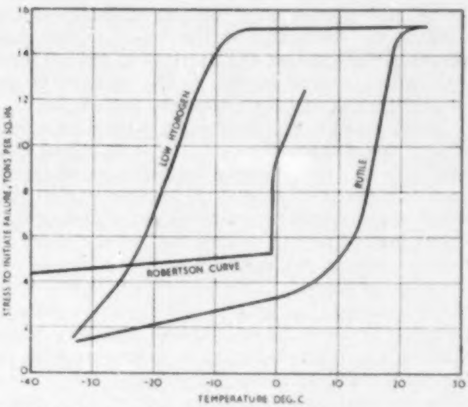
In these circumstances it is not strange to find that, apart from a somewhat general appreciation that the lower the transition temperature as determined, for example, by Izod or Charpy tests, the more liable is a steel to brittle fracture, no satisfactory correlation between brittle fracture failures and such properties has been established. This condition persists in spite of the tremendous efforts that are known to have been expended in trying to find some such correlation.

It seems clear that the liability of a structure to brittle failure can only be assessed on the basis of tests in which both the parent and the weld metals participate. If for no other reason than this the future exploitation of such tests as those of Wells in Great Britain and of Pellini in the United States will be awaited with considerable interest.

Crack severity

One aspect of the observation of Wells has, however, been neglected in this discussion, namely, the 'severity' of the failure in his tests. While in fig. 3 the relationship between stress and temperature for crack initiated is plotted, no account is taken of the severity of the cracks, assessed in the experiments by their length. With the varied experimental conditions, differences in this severity were noted; some cracks traversed the full width (3 ft.) of the specimens, whereas others were only of a few inches in length.

It is in this respect that a suggestion of Rankin from Colvilles' research laboratory proved par-



4 *Wide-plate test results for mild steel*

ticularly fruitful. When the Robertson curve is added to those of fig. 3, as has been done in fig. 4, a really comprehensive picture of the brittle-fracture problem becomes evident. The Wells curves show the temperature and stress conditions under which a crack is initiated from the artificial defect and dependent on the relationship between this point and the Robertson curve will be the progress of the crack. If the point is to the left and above the Robertson curve the crack will not be arrested—the failure will be complete. If the point is to the right and below the Robertson curve the crack will not propagate indefinitely but will be stopped in the plate material. This is entirely an attractive picture of the brittle-fracture problem and only further work will show whether, although the basic facts are correct, the interpretation has been oversimplified.

It must be realized that while the Robertson curves for plates are made under closely controlled conditions, and while the assessment of the experimental results is reasonably precise, at least for plates which are not particularly thick, such precision is not attained in the Wells test because the initiating defect, as it exists immediately prior to fracture, cannot, by the very nature of things, be other than variable. It is not unexpected, therefore, that the scatter on the Wells data is appreciable.

This lack of precision is, however, not unknown, and not necessarily greater than in other studies of transition behaviours and in the wide plate tests seems to be resolvable only by increasing the number of tests so as to establish the resultant curves with reasonable accuracy.

Effect of welding electrodes

One of the many problems remaining concerns the reason why the electrodes used in these experi-

ments play such a large part in determining the 'transition' behaviour of the welded specimens. As yet the elucidation of this problem has not been approached experimentally, so that opinion at the present time is to a certain degree speculative.

Three possible explanations have been advanced. One is based upon the fact that it is known that hydrogen in steel increases the transition temperature, and therefore with a rutile type of electrode there is the possibility of hydrogen diffusing into the parent plate and at the base of the artificial notch, creating conditions more favourable to the initiation of failure. This may appear to be a little far-fetched, and the general opinion at the present time favours a more mechanical approach, based upon either micro-fissuring or macro-cracking in the weld metal bridging the two saw cuts in the plate material (one on either side of the weld). These two latter suggestions do, however, emphasize the known fact that the role of the initiating defect is of major importance.

As a consequence it is justifiable to ask what happens in a wide-plate test in the absence of an initiating defect. The answer is that brittle fracture at low applied loads does not occur. This is borne out by the lack of success encountered recently in the United States, where an attempt was made to develop a test specimen in the form of a small pressure vessel for the purpose of studying the brittle-fracture problem. It did not prove possible to initiate brittle fracture in the pressure vessel until a wholly unacceptable design feature, the purpose of which was to provide a very major stress concentration, was incorporated in the vessel.

Such considerations, therefore, lead to the second inescapable prerequisite for brittle facture at low applied loads; there must be a defect in the weld zone, of sufficient magnitude in its influence, before fracture can be initiated.

Limitations of radiography

A statement of this type clearly summons before one's eyes a wide scope of experimental programmes to ascertain the quantitative aspects of the situation. But the question will necessarily arise as to whether the effort would be worth while. In pressure vessel construction, a potent tool in the form of radiography has been used by the manufacturers to ensure that gross defects do not exist in the pressure vessels when they are put into service. No one knows better than the experienced manufacturer the limitations of the non-destructive methods of examination he uses. It is well recognized within the industry that radiography is not necessarily competent to detect fine cracks in thick weldments.

It is also recognized within the industry that fabrication methods play an important part in the incidence of cracks and the reliable manufacturer will not use a cheaper method of construction if it is known to be prone to leave cracks or crack-like defects in the welded zone. With the use of radiography and well-established and verified practices, the possibility of leaving in a butt weld a defect of a magnitude of sufficient severity to lead to failure at low applied stresses is extremely remote, so extreme in fact that one is inclined to say impossible. Enthusiasts for the use of ultrasonic inspection techniques are inclined to emphasize the fact that here is a tool that can dispel the fear of leaving any defect, no matter how small, in a weld no matter how thick.

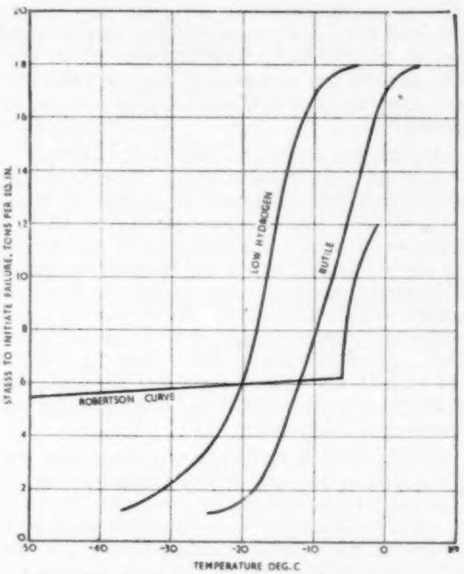
While this may be true, the merits and demerits of alternative methods of non-destructive testing fall outside the scope of this address. It is proposed, therefore, to leave this subject with the final thought that, whatever may happen in the future, so far as can be ascertained there is no known case of brittle failure at low applied stress having occurred in a welded seam that had been radiographed.

All butt welds in Class I pressure vessels can be radiographically examined, otherwise the welds themselves could not be made. It would appear, therefore, that the possibility of such vessels failing by the brittle-fracture mechanism is extremely remote, no matter what type of steel may be employed, because two of the necessary conditions for such failures, (*a*) residual stress, and (*b*) an initiating defect, are both absent: stress relief and non-destructive examination are demanded in all present-day British specifications for such vessels. There is no known case of brittle fracture of a Class I pressure vessel in service, even though such vessels have been in service for many years at temperatures well below any conventional transition temperature of the materials involved.

In view of the agreement between extensive service experience of Class I pressure vessels and the laboratory investigations briefly described, one is justified in asking what is the remaining problem in the experimental programme that has any importance to the manufacturer and user of pressure vessels, and why is so great an emphasis being placed upon steel selection by various competent bodies.

Selection of steels

The manufacturer has two aspects to consider: the possibility of a brittle fracture, (*a*) during construction, and (*b*) for vessels that cannot be submitted to an effective stress-relieving operation. In both instances residual stress of a high magnitude will be present, and, since there may exist the possibility of a defect of sufficient size to trigger off brittle fracture, it is necessary for the fabricator to consider carefully his choice of the steels available.



5 *Wide-plate test results for NDI steel*

In large constructions, where large tonnages of steel are involved, the economic aspects cannot be disregarded, for the extra price per ton of steel of improved notch ductility characteristics can be an appreciable percentage of the total manufacturing costs.

Fig. 5 is similar to fig. 4 but is for a steel (NDI) with somewhat better notch-impact properties. Three effects are worthy of comment. The temperature difference between the two Wells curves is not so noticeable in fig. 5 as in fig. 3, suggesting that with an improvement in the steel the influence of the electrode type is not so prominent. Secondly, with the two sets of specimens with root runs made with the low-hydrogen electrodes there is no substantial difference between the two series of results. With the specimens welded with the rutile electrodes there is a shift towards lower temperatures for the steel with the better notch impact properties. The third point to notice is that although the Robertson transition temperature is not markedly changed, the major influence of the steel quality has been to raise the stress level for the crack-arrest temperatures below the transition temperature.

Arising from the changes in the relative positions of the wide-plate test results and the Robertson curve, it can be seen that with the improved steel a lower temperature and a higher stress is on the whole necessary to initiate catastrophic brittle fracture. This arises from the fact that, except for stresses below 6 tons/sq. in., the curves for the wide-plate tests are to the left and above the Robertson curve.

We now have an adequate picture of the brittle fracture problem as it applies to pressure vessels, and it will perhaps be appreciated how futile it is to base the probability of failure on the conventional notch-impact tests. This, of course, is not to imply that a notch-impact test may not have some bearing on the problem, but rather to emphasize that its importance is confined to a qualitative assessment. At the same time it is not suggested that we are in possession of all the desired facts. It is well recognized throughout the British industry that the next most important point to establish is the influence of section thickness. The truth of this statement lies in the ready response made, by those organizations approached, to a special appeal that was made on behalf of the British Welding Research Association for the necessary funds to extend their work to plates of 3 in. thickness.

Types of defect

Also, further information is surely desirable on the significance of the type of defect producible in welded plates. It must be considered that the original defect explored by Wells is one that is not likely to simulate conditions that will exist in a well-constructed pressure vessel and it would be of considerable interest to have a clearer understanding of the more precise mechanism by which the defect operates. Such tests are expensive and time-consuming, and one has of necessity to curb one's impatience, but meantime it is submitted that the two researches on which attention has been focused have advanced the understanding of the brittle-fracture problem in pressure vessels to the point when definite use can be made of the data to the advantage of engineering industry.

To recapitulate the findings of the investigations mentioned, it can be seen that for brittle fracture at low applied loads to occur, three factors have to be present simultaneously, namely: (*a*) there must be residual welding stresses; (*b*) there must be a defect present of sufficient severity that it can be the point of initiation of the fracture; and (*c*) the structure must be at a sufficiently low temperature, which cannot be defined by conventional methods of testing.

There is only one reservation that seems reasonable to make at this stage, and that is that we still do not know sufficient concerning the influence of stress concentrations of a serious magnitude. It would seem, therefore, that it is permissible to associate the above conclusions with conventional good practice in design.

Problems of nuclear power production

Finally, some consideration might be paid to the

importance of this work in the field of nuclear power production. Here two special considerations are thought to apply. In this most recent of all power-production methods, the containment vessel (the reactor vessel) of the radioactive core is, for the gas-cooled graphite-moderated reactor, of a size and thickness that would appear at first sight to necessitate special treatment during manufacture. But is this, in fact, really such a problem? It is agreed that much of the construction has to be undertaken under site conditions, but it is also agreed that those site conditions can approximate quite closely to those appertaining in the average pressure-vessel factory.

The difficulties are largely those imposed by the methods of mechanical handling and assembly. The difficulties, however, are not of an insuperable nature; adequate planning of the constructional methods, provided they are based on the well-recognized requirements of experienced pressure vessel manufacture, will be an adequate safeguard against the introduction of defects of sufficient magnitude and orientation to initiate brittle fracture. Furthermore, the steel qualities employed can be of a type that not only has adequate resistance to crack propagation but is also characterized by freedom from laminar defects which, as is well known, can lead to the occurrence of more serious defects during welding.

For the containment vessels for other types of reactors, such as the pressurized water types, the problems are exactly those at present met with and overcome in present-day practice. The only major difference is that the thickness of the steel (possibly 6–8 in.) may exceed by a relatively small degree the thickness (5–6 in.) of vessels now quite frequently produced as a factory routine. In such instances the one factor that is of predominant importance is the adequacy of the non-destructive method of weld examination. This is a serious problem which does not need discussion at this stage as it will suffice to state that adequate methods are now available in those shops where such work has been undertaken in the past.

Effects of irradiation

The one remaining problem, therefore, in nuclear power production is the effect of irradiation by neutrons on the reactor vessel. The effect of neutron irradiation is becoming clearer as more experimental results are becoming available. Briefly, the evidence is that under neutron bombardment the transition temperature of a steel, measured by conventional notch-impact tests, is increased. The increase is determined by the extent of the irradiation, both time and density, and by the speed of the neutrons. The greater the neutron velocity the more potent its influence. Also, the temperature of the steel has an important part to play. It would appear that the maximum 'damage' to the steel can occur in the temperature range of 150–250°C. and that above 300°C. the damage can be annealed out.

Sufficient has probably been said, therefore, to indicate that the problem of the effects of neutron irradiation in reactors is not capable of simple solution until more accurate data can be obtained from actual service measurements of flux density. At the moment estimates can be made, and it has been stated that an increase of the transition temperature—determined from Charpy V-notch impact specimens—can be expected to be as small as a few degrees centigrade or as large as 40°C. in the case of the reactor vessels of the gas-cooled graphite-moderated reactors at present under construction in this country.

On the basis of the Wells wide-plate tests, figs. 3 and 5 show that, for the welds incorporating root runs made with low-hydrogen electrodes, the transsition temperature has barely changed, whereas the change in the transition temperature for the steel, determined by Charpy tests, was of the order of 25°C. Or again, if comparisons are drawn between the behaviours of the ordinary mild steel of fig. 3 and a notch ductile steel of the NDIV type, whereby conventional Charpy tests the transition temperature is decreased by approximately 80°C., it is found in the Wells test that the transition curve has been shifted only 15–20°C.

If the estimates of irradiation damage are reasonably accurate, and if the corresponding data determined as the result of the welded wide-plate tests can be relied upon, it is clear that with present-day good practice in design, workmanship, construction and erection, and with steels that have a long experience of industrial usage there is no need to anticipate brittle failures in nuclear reactor vessels now being produced for industrial power production.

Industrial gas manufacture

A new plant capable of manufacturing several million cubic feet of high purity oxygen and nitrogen per week is now being erected in Glasgow for British Oxygen Gases Ltd. A compressing station is also being built which will be capable of meeting the increased demands for compressed oxygen, nitrogen and air in the district.

Buildings on site will include bulk storage for liquid oxygen, an electrical sub-station, propane cylinder storage dock, dispatch office and boiler house.

All industrial gases, including argon, hydrogen and propane, will be distributed from the new works which is situated on a 25-acre site at Polmadie.

Phase diagrams

covering pressure, temperature and composition

Use of thermodynamic data to elucidate the cadmium-zinc binary system

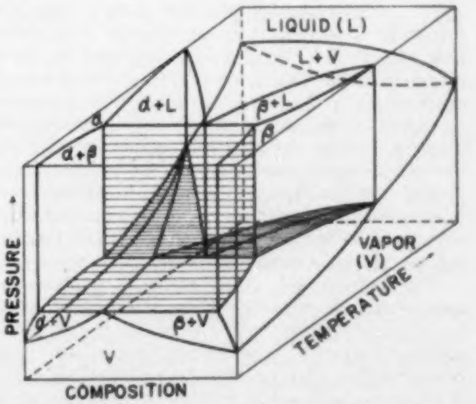
PROF. A. G. GUY and SHOTARO MOROZUMI

Most metallurgists are familiar with the ordinary temperature-composition phase diagram, plotted for a constant pressure, usually one atmosphere. In the following article, the authors have taken this a stage further and from thermodynamic-activity data have constructed a three-dimensional pressure-temperature-composition (P-T-X) diagram for the cadmium-zinc system. With the increased use of vacuum techniques such physico-chemical data are valuable, particularly so in the case of the cadmium-zinc system, since these two metals are recovered and separated by condensation from the vapour-phase in ordinary commercial operation. Professor Guy occupies the Chair of Metallurgical Engineering and Shotaro Morozumi is a Graduate Student at Purdue University, Lafayette, Indiana, U.S.A.

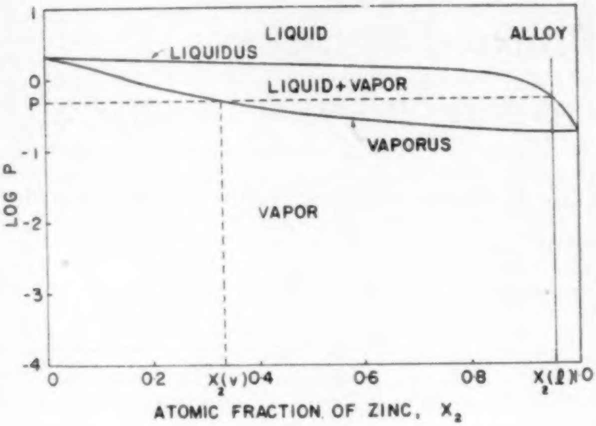
THE INCREASING USE of vacuum techniques, such as vacuum melting, in metallurgical operations calls for more general information about phase equilibria than that given by the ordinary phase diagram at one atmosphere pressure. The answer to this need can be supplied by the *P-T-X* diagram, in which pressure, *P*, is plotted as a variable in addition to temperature, *T*, and composition, *X*. The principles governing the general features of *P-T-X* diagrams are well known[1, 2, 3] but quantitative diagrams are almost entirely lacking. Even for a system such as cadmium-zinc, which has the dual advantages of commercial importance and experimental convenience, no *P-T-X* diagram was found in the literature.

In connection with an experimental study of vaporization in the cadmium-zinc system, an effort was made to construct a quantitative *P-T-X* diagram making use of thermodynamic data, thus extending the calculations made by Lumsden[4] for the *T-X* section at atmospheric pressure. The method employed was successful in producing the required diagram and appears to be generally applicable for this purpose. The method is described here together with the quantitative *P-T-X* diagram obtained for the cadmium-zinc system by its use.

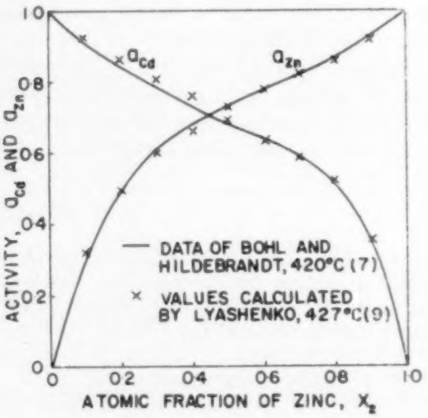
The ordinary phase diagram for the cadmium-zinc system is a simple eutectic with limited solid solubility,[4] and in formal treatments the *P-T-X* diagram in this case is drawn as shown in fig. 1, which has been adapted from Rhines.[3] That is, the vapour-solid equilibria (the front pressure-composition plane in the figure) are shown as the (inverted) analogue of the liquid-solid equilibria (the



1 *Typical P-T-X diagram for a binary eutectic system with limited solid solubility*



2 RIGHT *P-X section at 420°C. in the cadmium-zinc system*



3 BELOW *Activity data for liquid cadmium-zinc alloys*

upper temperature-composition plane). In the following treatment it is convenient to consider that the *P-T-X* diagram is composed of three relatively simple two-state* equilibria—solid-liquid, liquid-vapour, and vapour-solid—interconnected through a more complex three-state region of the diagram. The present calculations verify that the liquid-vapour equilibrium in the cadmium-zinc system is of the type shown in fig. 1. However, as is discussed later, the vapour-solid equilibrium is characterized by the analogue of a peritectic reaction rather than of a eutectic reaction.

The solid-liquid equilibrium is given adequately for all pressures below atmospheric pressure by the ordinary phase diagram at one atmosphere pressure. It is known that at very high pressures this diagram changes considerably. For example, a pressure of 30,000 kg./cm.^{2} increases the melting point of zinc by 129°C. and increases the melting point of cadmium by 187°C.[5] However, the change in pressure from 1 atmosphere toward zero causes the melting points to change by only a small fraction of a degree, and the other aspects of the solid-liquid equilibrium show similar stability.

**The term 'state' is used here in reference to the three states of matter, solid, liquid, and vapour.*

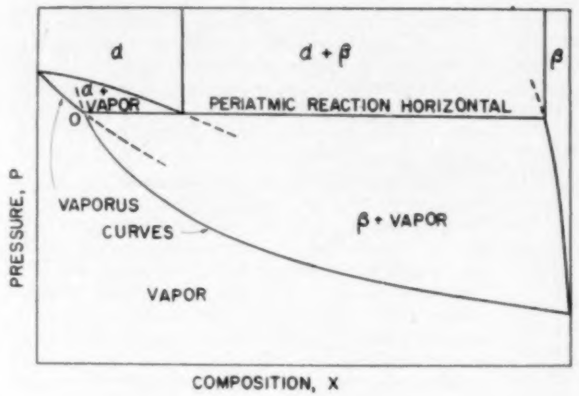
Determination of liquid-vapour sections

The two equilibria involving the vapour phase (liquid-vapour and solid-vapour) are conveniently considered at constant temperature rather than at constant pressure as in the case of condensed phases. The rear pressure-composition plane in fig. 1 shows the general nature of the liquid-vapour equilibria expected for the cadmium-zinc system. Consideration of the equilibrium between a vapour phase and a condensed phase will show how this type of *P-X* section can be determined quantitatively using thermodynamic activity data. The method employed here is an extension of that described by Vogel[2] for ideal solutions.

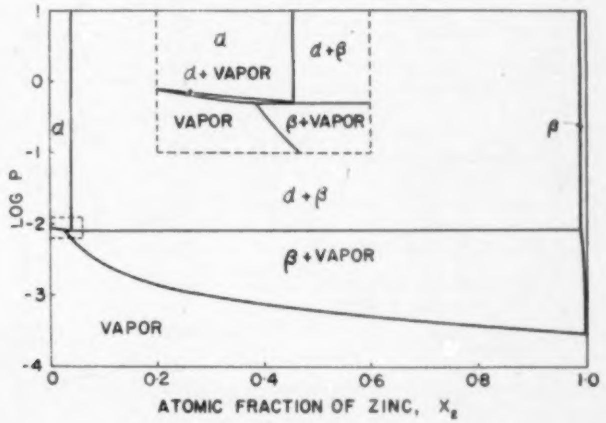
In the diagram of fig. 2 the liquid phase is the only phase present at high pressures. The vapour phase can first coexist over a liquid phase of composition $X_2\,(l)$ when the external pressure, P, is equal to the vapour pressure of the liquid solution. (In the following treatment the subscript 1 refers to cadmium and the subscript 2 refers to zinc.) In a binary solution the total vapour pressure is the sum of the partial pressures, p, of the two components, and therefore the condition for coexistence of the liquid and vapour phases is,

$$P = p_1 + p_2 \quad \ldots\ldots\ldots\ldots\ldots(1)$$

When the vapour phase can be considered to be an



4 *Schematic P-X diagram illustrating the principles of calculation*



5 *P-X section at 265°C. in the cadmium-zinc system*

ideal gas, as in the case of metal vapours at low pressures, the thermodynamic activity, a_1, of component 1 in a solution can be defined in terms of the vapour pressure of the pure component, p°_1, and the partial pressure, p_1, of this component over the solution[4] :

$$a_1 = \frac{p_1}{p^\circ_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Thus, equation (1) can be written

$$P = a_1 p^\circ_1 + a_2 p^\circ_2 \quad \ldots\ldots\ldots(3)$$

and the pressure P can then be determined from data on the thermodynamic activities and vapour pressures of the two components. The composition of the vapour phase, $X_2(v)$, in equilibrium with the liquid phase of composition $X_2(l)$ follows directly from Dalton's law, since the fractional pressure exerted by each component is equal to its atomic fraction in the vapour phase; therefore,

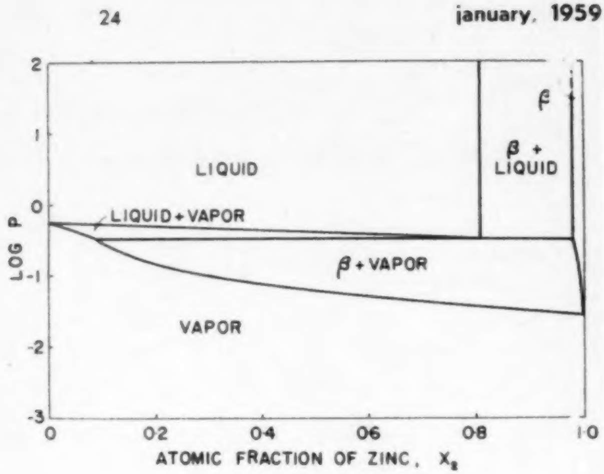
$$X_2(v) = \frac{p_2}{p_1 + p_2} \quad \ldots\ldots\ldots\ldots(4)$$

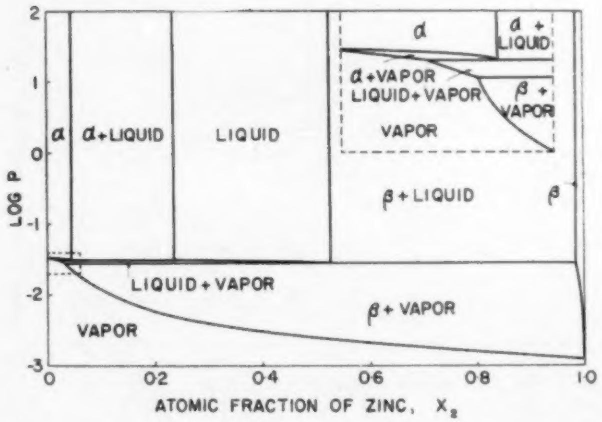
Equations (3) and (4) were used to calculate the *P-X* section shown in fig. 2 and also sections at 470 and 520°C. The vapour pressure data were obtained from Kubaschewski and Evans[6] and the activity data from Bohl and Hildebrandt[7], fig. 3.

Estimation of thermodynamic activities from the phase diagram

Thermodynamic activity data are available for the liquid phase in a number of binary systems and for the solid phases in somewhat fewer systems. However, in many cases these data have not yet been determined. It is fortunate that quite good estimates can be made under certain conditions if

6 *P-X section at 370°C. in the cadmium-zinc system*





7 *P-X section at 295°C. in the cadmium-zinc system*

the ordinary phase diagram is accurately known and if values of the heats of mixing are known or can be adequately approximated. The method employed for liquid solutions has been described by Chipman and Elliott[8] and it has been applied by Lyashenko[9] to calculate activities in cadmium-zinc alloys at 427°C. These calculated values are compared with the experimental data in fig. 3.

Lumsden[4] has shown that the activities of the solid-solution phases in the cadmium-zinc system can also be obtained from the phase diagram. His values for the infinitely dilute solutions are:

$$RT\ln\gamma_1 = 6560 - 3.40T \quad ......(5)$$
$$RT\ln\gamma_2 = 4170 - 1.52T \quad ......(6)$$

where the activity coefficient, γ_1, is defined by the relation $a_1 = \gamma_1 N_1$, and the pure components are taken as the standard state. There is little error in neglecting the variation of the activity coefficients with composition over the small range of compositions of the solid solutions in the cadmium-zinc system. Brown[10] has verified the relation of equation (5) and has suggested a slight modification of it.

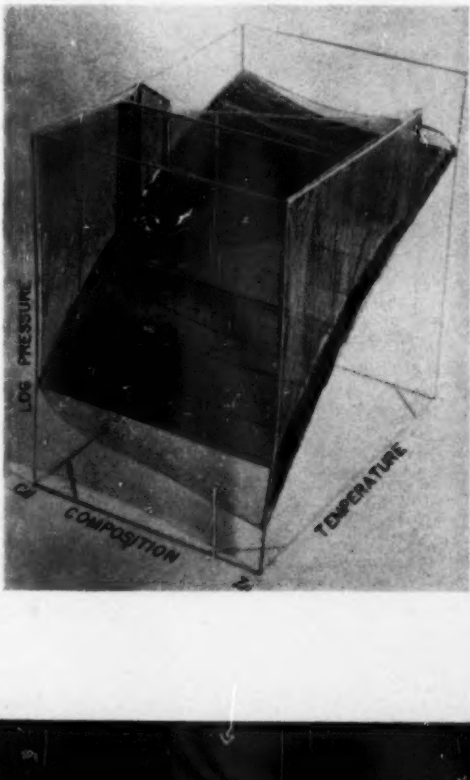
Determination of the solid-vapour sections

P-X sections for the equilibria of solid and vapour can be calculated in the manner described above for liquid-vapour equilibria except that the region of coexistence of two solid phases must be taken into account. This can be done by calculating the boundaries of the α + vapour two-phase field starting from the cadmium side of the diagram, as shown schematically in fig. 4, and similarly calculating the boundaries of the β + vapour field starting from the zinc side of the diagram. These boundaries can be determined using equations (3) and (4), provided that the activities are

now understood to be those of the solid solution. In fig. 4 the boundaries of the α + vapour field are shown extended into the region of metastability to emphasize the similarity between this two-phase field and the liquid + vapour field in fig. 2. At the point of intersection, 0, of the two vaporous curves the α and β phases are in equilibrium with vapour of the same composition and therefore they are in equilibrium with each other. At pressures higher than that corresponding to point 0 the vapour phase disappears in the central region of the diagram between the single-phase α field on the left and the β field on the right, and only a mixture of the two solid phases remains. The curve bounding the region of existence of the vapour phase has been called the vaporous, following the practice of Ricci.[11] It is proposed that the three-phase axis be called the *periatmic* reaction horizontal and that the corresponding three-phase axis in the vapour-solid region of fig. 1 be called the *euatmic* reaction horizontal[12] by analogy with the familiar peritectic and eutectic reactions involving the liquid phase.

The activity data of equations (5) and (6) were used to calculate the *P-X* section at 265°C. shown in fig. 5, and also sections at 150 and 210°C. All of these sections contained a periatmic reaction, rather than a euatmic reaction. Experimental corroboration of this calculated result is supplied

8 *Space model of the P-T-X diagram for the cadmium-zinc system*



by the data of Scheller and Treadwell[13] on vacuum sublimation of cadmium-zinc alloys. These authors reported that a vapour containing 1·14 wt. % zinc was given off during the initial sublimation at 250°C. of an α solid-solution alloy containing 1·51 wt. % zinc. Their relative concentration values are consistent with a periatmic reaction, whereas, if the reaction were a euatmic, the vapour would have been richer in zinc than the alloy.

Determination of liquid-solid-vapour sections

The most complex *P-X* sections are in the three-state region of the *P-T-X* diagram, fig. 1, where the three two-state equilibria—solid-liquid, liquid-vapour, and vapour-solid—interconnect. There are two types of section in this region: one type is in the range of temperature between the eutectic temperature and the melting point of the lower-melting component (cadmium); a somewhat less complex type of section is in the temperature interval between the melting points of the two components. It is convenient to begin with a discussion of the latter section.

The section in fig. 6, at 370°C., was calculated by a combination of the procedures used for the sections of figs. 2 and 5. The curves bounding the liquid + vapour region were determined using equations (3) and (4). The activity values were extrapolated from the experimental data of fig. 3 using the equation[14]

$$\frac{d\ln a_1}{dT} = \frac{-L_1}{RT^2} \quad \ldots\ldots\ldots\ldots \quad (7)$$

and relative partial molal heat contents, L_1, determined by Bohl and Hildebrandt.[7] The boundaries of the vapour + β region were determined in the same way as for the vapour-solid section in fig. 5. The intersection of the vaporous curves of the liquid + vapour and of the vapour + β regions determined the location of the periatmic reaction horizontal.

The more complex section, fig. 7, which was calculated at 295°C., was determined in a manner similar to fig. 6. Three vaporous boundaries—vapour + α, vapour + liquid, and vapour + β—were determined in this case, and the two intersections determined the two periatmic reaction horizontals.

Construction of the space model

The three-dimensional model of the *P-T-X* diagram for the cadmium-zinc system, fig. 8, covers a temperature range of 150 to 520°C., and a pressure range of 10^{-8} mm. Hg to 760 mm. Hg (atmospheric pressure). Therefore the top of the space model is the ordinary phase diagram (*T-X*

section) at atmospheric pressure, and the same T-X section is continued down to the pressure at which the three-state region first appears.

The liquid + vapour region of the diagram was constructed on the basis of the P-X section of fig. 2 for 420°C., and similar sections at 470 and 520°C. Likewise, the solid + vapour region was constructed from the section of fig. 5 at 265°C., and similar sections at 150 and 210°C. The vapour composition on the periatmic reaction horizontal approaches pure cadmium at low temperatures, and is only 0·01 atomic fraction Zn at 150°C. The three-state region in the centre of the space model was constructed on the basis of figs. 6 and 7. Independent data concerning the location of the boundaries of the α + liquid and β + liquid regions was also obtained from the ordinary phase diagram, and the calculated values were adjusted to agree with these data in constructing this portion of the space model.

The space model was built within a frame approximately 15 × 22 × 22 in. made of $\frac{1}{8}$ in. balsa wood strips. The ordinary phase diagram (at the top of the model) and the two one-component diagrams for the pure metals (at the two sides of the model) were also made of $\frac{1}{8}$ in. balsa wood strips. The remaining P-X sections were made of $\frac{1}{16}$ in. balsa wood, and each assembled section was then cemented into the frame. Finally, the various phase-boundary surfaces were delineated by being covered with transparent cellophane. Cellophane of six different colours was used in order to show clearly the various phase-boundaries in the space model. Some difficulty was experienced with distortion of the thin balsa strips, as can be seen in the front and rear planes in fig. 8.

Summary

This work has shown that a complete P-T-X diagram can be calculated from the thermodynamic-activity and vapour-pressure data for a binary system. In the case of the cadmium-zinc system the calculations revealed that a periatmic reaction (analogous to a peritectic reaction) occurs in the vapour-solid equilibrium, even though the liquid-solid reaction is a eutectic.

The authors are grateful to Drs. F. N. Rhines and F. J. Dunkerley for their helpful discussions of this work.

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4,000-ton forging press

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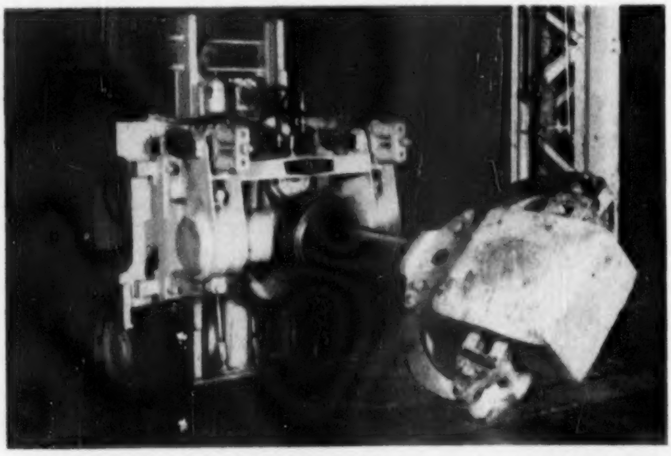

Stock for forging in the new press is handled by the mechanical manipulator which takes the form of a hydraulically-operated arm mounted on a fork-lift truck. The machine is of Salem Brosius design and is made under licence by Head Wrightson & Co. Ltd.

The handling of such large sizes during hand forging would clearly be impossible by the usual method, namely suspension from an overhead crane and manipulation by tongs. A mechanical manipulator has, therefore, been brought into use, which is essentially a hydraulically-operated arm, incorporating a means of gripping the stock, mounted on a fork-lift truck.

4,000-ton forging press

New installation at aluminium works

The new hydraulic press in operation for the production of large hand forgings

NORTHERN ALUMINIUM COMPANY'S capacity for the production of hand forgings has been greatly increased by the recent installation at their Birmingham Works of a 4,000-ton direct-acting hydraulic press. It is also available for closed-die and no-draft forgings and for the pre-working of cast stock prior to rolling and extrusion in the company's works at Banbury and Rogerstone.

The press, by Becker and Van Hullen, was originally installed in the Dornier Works, Germany, and after the war was confiscated by the Dutch Government as war reparations. It was acquired by the firm of Van der Heist and Zonen, of The Hague, for the pressing of automobile body parts, and before installation at Birmingham it has been extensively rebuilt according to recommendations made by the Loewy Engineering Co Ltd.

In its original form, the press was too high for Northern Aluminium Company's forging bay, the method of retracting the ram being by two cylinders mounted at the top of the press; the main alteration has, therefore, been the replacement of these by two push-back cylinders, so reducing the height to 27 ft.

The press is fitted with ejector gear which takes the form of a 24-in. dia ram housed in a foundation 17 ft deep. From the bed plate rise the four main columns, 16 in. dia, surmounting which is the top crosshead. Below this is secured the main ram, 53 in. dia, on which the main cylinder, with the bolster secured to its lower face, moves up and down. Because of this principle of operation the main cylinder has guides at its top and bottom giving very accurate alignment between the upper and lower platens. The working space between the columns is 7 ft and the press has a stroke of 6 ft, which permits 9 ft 1 in. of daylight between top and bottom platens.

Operation

Operation of the press is by means of a modern system of finger-tip control through electro-hydraulic valves with a range of speeds varying from 0·08 to 0·50 in./sec. This variation in speed is achieved by the selective use of 12 Fraser mono-radial pumps each driven by a 50-h p motor capable of delivering oil to the press at a rate of 20 gal/min. To lower the cylinder, oil is passed into it from a 2,500-gal refill tank under an air pressure of about 50 lb/sq in.; when contact is made with the work the prefill valve closes and the pumps take over, delivering oil direct to the press.

The press was originally laid down to increase the scope of the hand forgings that could be offered by the company, especially for use in the aircraft industry, and among those already produced are several weighing 1,500 lb each. However, used in conjunction with the 45,000-lb hammer already installed, it will also enable the company to offer bigger closed-die forgings, up to about 700 lb in weight, and it has already proved its usefulness in enabling cast stock to be pre-worked more economically, and in bigger sizes, than hitherto.

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N A D F S Spring lectures 1958

No 5

Hardness testing

Concluding the synopses of the 1958 series of N A D F S Spring lectures for younger members of the industry, we reproduce below some of the points made by Mr. G. H. Jackson, technical officer, N A D F S, in the final lecture given on May 20. Mr. Jackson considered the question of ' hardness ' in general, pointing out that it was not an easy property to define, and then explained how, subject to certain difficulties, hardness could be measured to within various degrees of accuracy

IF TEN PEOPLE were asked to define ' hardness,' said Mr. Jackson, one would get ten different answers. Although ' softness ' was just as indefinable, it was easier for one to envisage the difference between ' softness ' and ' hardness.' The two properties were relative, in so far as something was harder or softer than something else. Differences in softness were discernible by touch. For example, a range of rubbers of increasing hardness would readily be sorted by touch, but a degree would be reached when further increase could not be so determined. Resistance to indentation had come to be accepted in most quarters as a practical if vague criterion of hardness.

Elasticity and plasticity

Resistance to indentation, however, had to be examined in some detail to obtain a clear conception of ' hardness.' Indentation suggested a local deformation as distinct from those properties measurable by compression or tension, in which a complete mass or section was subjected to the measured forces. Such a suggestion of local attack conjured up the experienced differences of prodding, say, a piece of rubber and a piece of putty. The rubber completely recovered after the force was removed, but the putty would retain the impression. Both were soft to touch. It was obvious, therefore, from this simple illustration that elasticity and elastic recovery were both involved.

There had been much difference of opinion as to whether elasticity and elastic recovery were involved in hardness testing, and whether they should be included in any method used. Hertz had suggested that ' the hardness of a body was to be measured by the normal pressure per unit area which must act at the centre of a circular surface of pressure in order that in some point of the body the stress might just reach the limit consistent with perfect elasticity.' Meyer, on the other hand, declared that ' elastic deformation which was so small that it could be measured only by means of refined methods played no part in forming the conception of hardness.' O'Neill was attracted by the method of making measurements on unrecovered indentations in which both elastic and plastic deformation were incorporated in the test. Obviously Hertz's principle was readily applicable to brittle bodies where the elastic limit was easily observed by the formation of a crack, but this would not be the case in ductile metals. On the other hand, it was frequently impossible to produce reliable permanent indentations in brittle material. Roudie had stated ' elasticity and hardness were two inseparable manifestations of molecular energy which dynamic methods alone could define and measure.'

Static and dynamic tests

Those differences of opinion, continued Mr. Jackson, indicated the complication of indentation hardness measurement. Further, the usual methods in use today were so called ' static tests,' in which for all intents and purposes a time element beyond that necessary to establish some sort of stability was not considered. But it could be shown that hardness could be considerably affected by dynamic application of either the indentor or the material to be indented. For example, water was undoubtedly soft—to the touch—and yet became hard if dived into from a great height or at a great speed. Many other examples of the dynamic effect could be called to mind—the soft buffing wheel of swansdown which, when rotated at high speed, became a compact, hard mass of considerable use in polishing hard materials.

There were many other examples. A simple conception of a dynamic test was the measurement of hardness by the rebound of a falling indentor. The harder the material the higher the rebound. Tested by such means, india-rubber would emerge as a very hard material while it was, relatively speaking, very soft.

Mass effect

There was yet a further complication in the hardness test, particularly of heterogeneous materials in which there was mass effect. Very few materials were absolutely homogeneous and many, in fact, were made up of very hard constituents in a soft matrix. In such a case, mass hardness was generally considered by testing a volume of metal which was very large when compared with the actual size of individual constituents. Simple examples of mass hardness effects could be shown by considering the case of many ceramics and compacts which were removed easily by a hand file in mass, but the file would in turn be scratched by the individual particles of alumina or other oxide or carbide which were worn away. Therefore, the mass hardness of the file was greater than that of the ceramic compact, but the particle hardness of the compact was greater than that of the file. O'Neill had pointed out that the mass hardness of a metal at a given temperature might be reported as the reaction which it exerted towards local indentation, which reaction should be expressed in terms which recognized viscosity and elasticity and which allowed for the fact that the intensity or degree of an indentation might affect the specific reaction. It was quite amazing, in view of these diverse factors, that a numerical value of any consistent use for specifying hardness had ever been possible.

It could also be claimed that metallic hardness should be considered from at least two other points of view, namely, the relative or absolute hardness and that of strain hardenability. An indentor came to rest in a material when the load acting upon it was supported by whatever it was that was opposing indentation. It was certain that it was not the material itself that was necessarily preventing further penetration, but the overstrained, cold worked and crushed remains of the original material backed by material that was strained but not crushed, that provided a hardness index. The unstrained, non-cold-worked material under test was not discovered by indentation penetration, and in any case it was likely that even if discovered it would be of little use. It was not intended to delve too deeply into the theories and considerations of the various aspects mentioned, but reference to them had been made to emphasize the complexity of the subject and, in particular, the factors involved when comparison and conversion of the results of different methods were contemplated. They also had a bearing on considerations of the interrelation of other properties of metals when hardness was to be used as a means of measuring or indicating them.

The objects of the application of a hardness test should be clearly understood. The accuracy of a given method or procedure was influenced by many factors other than the fundamental considerations already mentioned. High-order accuracy for research work involved the application of many precautionary measures and of many correction factors. In commercial testing, the objects of the investigation or inspection within the requirement of commercial output. Despite the fact that some accuracy could and often had to be sacrificed to meet these conditions, it was still necessary to have consistency and reliability by control of obvious factors affecting the test.

Many were the methods that had been investigated for the production of static indentations to give numerical values of hardness. Sphere, cone, cylinder and prism had been used as a geometric form of indentor by some twenty well-known investigators, each of which produced a method or equipment which no doubt had a specific purpose, but many of which had fallen out of everyday use. Today the most well-known commercially and technically applicable methods were the Brinell, the Rockwell and the 136° Diamond. Of these, the Rockwell had gained favour principally because of the speed at which tests could be made, making a larger quantity inspection of vital components possible. Brinell was rarely used for the testing of materials harder than 450 BHN; after that, a diamond as the penetrator was considered essential.

Precautions necessary to secure consistent Brinell results

The author proceeded to describe with the aid of slides the Brinell hardness tester, pointing out that some time had been spent on that test because of its wide use in the forging industry as a result of the range of materials more usually encountered, and it was hoped that, by commenting upon some of the underlying theories it would emphasize the importance of minimizing error by the control of as many variables as lay within the hands of the operator. The precautions necessary to ensure a consistency of results were outlined as follows.

Wherever possible the surface to be tested should be flat, normal to the penetrator and of a good surface finish; the sample always be correctly and firmly held. The equipment, particularly the load-actuating mechanism, should be kept and maintained in first-class order, and the steel ball should not be looked upon as an indestructible and non-consumable item, but it should be checked or changed frequently.

One should always work to the same time of application, preferably 10 sec., and always ensure that the site of test was adequately supported by sufficient surrounding metal, or was as far away from previous Brinell impressions as possible.

Differences in the appearance of the impression

could mean differences between samples and, particularly if the same material was being used, a change of impression from, say, ridging to sinking, was worthy of thought, comment and perhaps further investigation as it indicated a change of other properties.

Practical application of the Rockwell test

To summarize the principle of this operation, said Mr. Jackson, the Rockwell hardness number was based on the additional depth to which a test point or ball was driven by heavy load over and beyond that depth with the same penetrator by a pre-determined initial load. The major load was applied and removed through a dashpot mechanism, the hardness number automatically being recorded on a dial in terms of depth of penetration under the major load and whilst the minor load was still being applied. Thus, the partial recovery of the depth of indentation due to elasticity occurred when the major load was removed, but an important point not to be overlooked was that because measurement was made after removal of the major load, no deformation of the fixture or machine was included in the reading. The units of Rockwell were chosen so that one point of hardness was to a depth of only 0·002 mm. and obviously, therefore, the depth-measuring system had to be accurate, the load properly applied and the friction of the whole system reduced to a minimum.

Many different scales, said Mr. Jackson, were available for use in various considerations with the Rockwell test, thus making it very versatile in application. Of these scales the most well known was undoubtedly the 'C' scale which utilized a diamond cone and, perhaps less frequently, the 'A' scale with a 60-kg. load and 120° diamond, as used for testing cemented carbides and other extremely hard materials.

The Rockwell hardness number was not capable of definitions in terms of the fundamental units of length, mass and time. Although the loads might be defined, the value of each unit of depth also defined by such variations as the shape of the penetrator, accuracy of loads, depth-measuring devices, machined rigidity, method of applying the load, lubrication, alignment, dirt and scale between working surfaces prevented any translation of definition into a specification. A.S.T.M. specifications did no more than aim at indicating how to use the equipment rather than attempt a definition of Rockwell hardness. Unlike the Brinell test which was specified by the ball load and the diameter, it was only fair to point out that the Rockwell was far more complex and was to a much greater extent empirical because of many arbitrary considerations of design. Nevertheless, the Rockwell was in very extensive use today for production testing and, providing those factors known to influence the test were controlled and because the machines being made today were superb equipment, the method had a definite value in production control.

Surface preparation such as producing a flat as in the case of Brinell was less necessary in the case of Rockwell. This was of a very great attraction where thinly case-hardened articles were under test or where some surface condition was being investigated.

Mr. Jackson concluded that Rockwell testing was at its best on hardened materials and had an approximate line of demarcation, one would say where the Brinell tended to lose its accuracy.

136° diamond penetrator test

Discussing the 136° diamond pyramid hardness method, Mr. Jackson said that this followed the Brinell principle in so far that a definite shaped indentor was passed into the surface under test with a suitable load, after which diagonals instead of a diameter were measured and the hardness number calculated by dividing the load by the surface area of the indentation.

The indentor was always made of diamond and was in the form of a pyramid with a between-face angle of 136°. The loads applicable to the method in the case of the Vickers machine, first introduced in 1925 by Smith and Sandland, varied from 1 to 120 kg. with a standard range of some six or seven fixed loads. The Vickers method of hardness testing had always been considered as a standard method of precision testing and as such had in many instances been confined to the laboratory rather than the production, although many machines utilizing the pyramid impression had been produced for direct reading of production work.

The apparatus for testing by this method had to be designed to apply a steady load without any impact and in which friction of all moving parts had to be reduced to an absolute minimum so that the actual load on the penetrator was correct to less than 1%. The test was again essentially a static test and it was required by the relevant B.S. Specification that the load be applied for 15 sec. Wherever possible the applied load had to be as large as possible, taking into consideration dimensions of the test piece and its ultimate hardness in order to assist measurement of the diagonals which was carried out with an ocular micrometer. The reading was in microns. Such a measuring device must, according to B.S.427, measure to ±0·001 mm.

Various instruments utilizing the Vickers principle were available today, including the Tukon tester manufactured in the U.S.A. and the Firth

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Pyrophoricism in metals

Some problems of spontaneous ignition

HENRY ALLEN

Although regulations have been laid down to obviate the risk of fire hazards in most spheres of metal working, one form of fire hazard requires further study. This hazard, pyrophoricism, or spontaneous ignition, is particularly acute with the newer metals and their alloys. Mr. Allen, who is manager of industrial relations, British Divisions, The Yale & Towne Manufacturing Co., considers the problem and some of the preventative measures which are being evolved

THAT METALWORKING involves fire and explosion hazards is amply recognized in the considerable blanket of statutory obligations and other safety techniques that comprehensively cover processing, storage and handling of metals of all kinds, but there remains a sphere of accident causation and consequent accident prevention coding that needs to be more thoroughly explored. Ignitions and explosions occur spontaneously—and experience is now indicating that the newer metals and their alloys have a higher degree of pyrophoricity than the known traditional ones. Pyrophoricity—a new word to describe the tendency of metals spontaneously to ignite—is in fact coming under critical study as the applications of the metals multiply, as processes become more intricate and, consequently, as the need for tightening up safety precautions grows.

Causes of pyrophoricity

Certain facts have been established. One of the chief causes of spontaneous ignition in metals is the exposure of a large amount of surface to oxidation in air with consequent evolution of heat. Particle size is a key factor. As an example, zirconium reduced to fine powder where the average particle is 3 microns is highly pyrophoric, but in structural form the metal can withstand temperatures above 3,000°F. without igniting, and zirconium powder where particles are 12-micron size does not ignite at red heat. Similarly, uranium powder will spontaneously ignite at room temperature if it is blown into the air in a cloud.

Some metal powders have also been shown to be pyrophoric in carbon dioxide and in nitrogen and there is clear evidence that reaction with water is a notable factor in spontaneous ignition. In the problem of water reaction there are two elements that have to be separately considered. There is the reaction that arises when the metal is exposed to room temperature and there is that which follows when water contacts molten or hot metal. The latter is a more familiar causative, and an accident potential that standard safety codes have amply covered.

The alkali metals figure prominently in the first context. Substances like potassium, sodium, lithium and so on oxidize rapidly in air and have very sharp reactions with water. Explosions and fires that have occurred—and they are lamentably frequent—with magnesium, titanium, thorium—in the course of processing and handling have shown pyrophoric heating and subsequent ignition sometimes when there is no external source of heat. It is essential that storage and handling under some non-reactive liquid or gas be established as the safe working rule, for the alkali metals in the pyrophoric group. Potassium is quite safe under inert gas protection; lithium under an oxygen-free liquid such as toluene; and sodium under kerosene or naphtha. Inert gases such as argon and helium will effectively control the hazard of ignition in such metals as zirconium and titanium during processing at high temperatures.

Sometimes spontaneous ignition occurs under special circumstances. It has been observed, for instance, that if magnesium or zinc die-castings are immersed for a prolonged period in chromic acid solution, an ignition risk arises. It is recommended that magnesium die-castings be washed immediately on removal from the solution in cold water, afterwards being coated with a mineral oil, and that zinc castings be dipped in a diluted solution of trisodium phosphate which will have the

effect of removing the chromatic film. The theory is that the prolonged immersion in the chrome creates a finely divided condition and that with magnesium die-castings, for instance, a precipitate is formed, such as a magnesium aluminium compound in fine particle form. When dried in air the powdery film becomes highly pyrophoric.

In the study of pyrophoricity, a fruitful field for inquiry is with the hazardous combinations of metals, though here again the standard practice of safety has already covered the position pretty thoroughly. But there remain some hazardous combinations which are still being discovered, often in circumstances that involve a dangerous experience. Individuals find out more or less by chance and not always under laboratory conditions that, to take an illustrative case, methyl chloride in contact with aluminium can form spontaneously combustible aluminium methyl.

Preventative measures

Control techniques are gradually being evolved. It is now held, for instance, that boron trifluoride is highly effective for the control of fire risk in heat-treatment furnaces using magnesium. It is taking the place of boron trichloride gas. There has also been much useful research into the control of aluminium-water explosions. Some research specialists believe that coating containers into which the molten metal is put, with such a substance as black mastic paint, will do much to obviate the risk of the explosion of molten aluminium in water.

Another point that has to be mentioned is the problem of sludge disposal when the pyrophoric metals are machined or polished, the dust being collected in a precipitation-type separator. There arises the hazard in such a set up of reaction between the metal dust, the liquid of the collector and the coolant. About the only effective safety code for this particular problem is the meticulous removal at the end of every workshift or day of the sludge, and its subsequent destruction or alteration into a non-combustible state by treatment with, for instance, ferrous chloride.

It is becoming apparent that spontaneous combustion in metals is a bigger problem from the safe-working angle than had first been realized, but the amount of research and experiment now in hand holds good promise soon to illuminate this difficult matter. One of the avenues of inquiry is into the control techniques to be followed if, despite safe-working codes, a fire or explosion occurs. Here the best source of advice is undoubtedly the local chief fire prevention officer, who will detail the complicated control systems. Fire extinguishment is a subject for specialist direction and every plant should document the techniques to be followed and train personnel in their use. Potassium fires, for instance, can be swiftly aggravated if the wrong extinguisher is used; carbon dioxide can form an explosive compound if used on a potassium fire, and similarly foam, soda acid and carbon tetrachloride must never be used with sodium. All such important points will be fully detailed by the fire prevention authorities.

There are still many unknown factors both in the causes of pyrophoricity in metals and in its control, but enough research results are now coming through to give promise that it is simply a matter of a relatively short time before this aspect of metalworking in safety is thoroughly reviewed. Meanwhile, it is the task of the executive responsible for accident-free working to note current research findings.

Hardness testing

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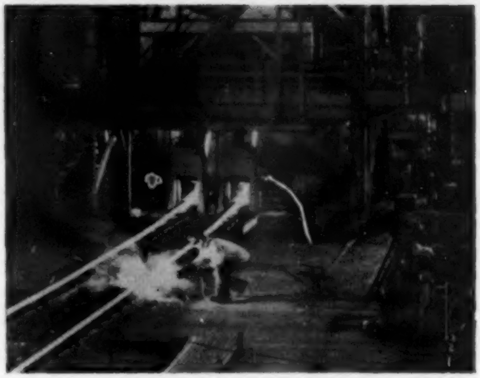
Hardometer. In the case of Firth Hardometer the load was applied through specially calibrated spiral springs and incorporates a suitable trip mechanism to prevent overloading. The machine was more of a workshop model than the Vickers, the load could either be fixed at 10, 30 or 120 kg., or variable loads from 2 to 40 kg. were available. The same phenomenon of ridging and sinking was observed in this test, as was quoted under Brinell testing, but it was made noticeable by a bulge effect, concave or convex, to the sides of the square impression. As in the case of the Vickers machine hardness values were obtained from a definite readable unit, *i.e.* 0·001 mm.

It was obviously essential, said Mr. Jackson, in the case of the 136° diamond pyramid hardness to have properly prepared surfaces, although, because of the very slight depth of penetration, flat surfaces were not necessary. To obtain the accuracy that the machine was capable of giving it was essential that the Vickers impression should be very clearly defined to enable measurements to be taken and, as mentioned under Rockwell testing, correct positioning, correct mounting, cleanliness, care of the diamond, the machine and frequent calibration of the ocular micrometer was essential if consistency was to be maintained.

Noise in industry

The new 'Foundry Noise Manual,' published by the American Foundrymen's Society, Des Plaines, Illinois, U.S.A. ($4.75), has direct application to the noise problems confronting general industry. A comprehensive reference, it explains in easy-to-understand terms the scientific principles involved in noise control. It describes the effects of noise on hearing and offers practical solutions for common noise problems.

The material is intended to provide management with information to meet industrial requirements, for adequate protection of employees while on the job, and for safeguarding company interests in relation to job placement.



Continuous casting

Twin-strand machine for steel

The twin-strand continuous casting plant at Barrow Steel Works showing steel billets being cut to length

THE CONTINUOUS CASTING machine at Barrow Steel Works Ltd., where experiments in the continuous casting of steel have been in progress since 1952, has been modified so that twin-strand continuous casting of billets and small slabs is now possible.

The modified machine, which has double the capacity of the former unit and is equipped with automatic control, operates at speeds of between 220 and 360 in./min. when casting 2-in. square billets—at least twice as fast as any other known continuous casting plant. Normal performance with billets of this size is a production rate of 15 tons/h. Despite these high casting speeds, the machine is only about 29 ft. tall to the top of the mould, the latter being 32 in. long.

Electric-arc furnace

Hot metal for the process is supplied from a 7½-ton capacity electric-arc furnace, which is tapped into a preheated ladle of the same capacity. Steel is teemed from the ladle into two separate tundishes simultaneously, a small transverse launder being used to divide the metal supply. The tundishes, like the ladle, are preheated and fired during casting by means of specially developed oil burners. An anti-swirl nozzle of Barrow design fitted to the bottom of each tundish ensures an even and steady flow of metal into the mould.

On emerging from the reciprocating copper mould, the billet passes through a series of water sprays and is solidified before it reaches the withdrawal rolls. At the base of either strand there is a single pair of rolls actuated by a power cylinder which bends the billet in order to discharge it horizontally on to a roller path, where it is straightened under its own weight and then cut to length. The extent of the cooling bank facilities available determines the length of the billet; lengths of up to 150 ft. have been obtained, though 30-ft. billets or shorter are standard practice.

Automatic control devices are employed to stabilize the level of the liquid metal in the mould during casting. This leads to greater reliability in operation as the entire production sequence proceeds automatically from the moment when casting begins; it also aids uniformity and consistency in the finished product. By giving greater flexibility, the twin-stranding arrangements ensure greater reliability and little or no loss of yield. Because of the close temperature control exercised, casting times may last up to 1¼ hours; longer casting periods are feasible and for a 7½-ton cast have been extended to two hours without adverse effects on the steel.

Good quality billets

The twin-strand plant at Barrow is designed to produce billets from 2 in. to 4 in. square and slabs up to 12 in. by 4 in. Much of the experience gained so far has been in the range of carbon steels containing between 0·05 and 0·85% C. For these steels, the average yield of commercially sound material runs between 98 and 99%. Equally good yields have been obtained with low-alloy steels, including silico-manganese spring steel and high-sulphur free-cutting steel, and stainless steels. In subsequent rolling and forging processes, continuously-cast billets and slabs have shown physical properties fully comparable with those produced by conventional methods.

'Incanite' cast iron

A new leaflet, No. VIIC on Incanite, has been issued by the Incandescent Heat Co. Ltd. Incanite is a metallurgically-controlled high-duty cast iron produced in four basic grades.

Progress in welding research

The last annual report of the British Welding Research Association announced the transfer to Abington of the metallurgical laboratories and staff in September, 1956. The annual report for 1957-58 points out that during the year, which is the first full year during which all the Association's researches have been carried out at Abington, the process of amalgamation and integration has continued smoothly and can now be considered complete. The expectation that the transfer of the metallurgical laboratories to Abington would facilitate collaboration among the staff has been more than justified by results in the past year. The recent report outlines some of the research work covering ferrous and non-ferrous metals and engineering research. Some extracts from the report are given below

Ferrous research

Welding of low-alloy steels In previous work on the welding of low-alloy steels it has been difficult to examine the effect of hydrogen by continuous variation over a range. Using covered electrodes, either relatively high or reasonably low hydrogen contents can be obtained but it is not easy to obtain intermediate values. Accordingly, work is proceeding to develop a technique for the controlled introduction of hydrogen. Inert-gas shielded metal-arc welding with a bare wire is being used, and hydrogen is being introduced either in the gaseous form or as water vapour. Useful information has already been obtained, and it will soon be possible to standardize the technique, so that the amount of hydrogen introduced into the weld metal will be completely under the control of the experimenter.

Cracking in welded gas mains In 1945 the first welded gas mains began to show cracks, most mains up to then having been riveted. Laboratory research at Cambridge and Durham Universities was carried out to simulate stress-corrosion cracking by the use of laboratory-made gas liquors, and it was eventually shown that this cracking could arise from solutions containing NH_3 and HCN together with CO_2 and H_2S alone or together. Both the laboratory work using the synthetic gas liquors, and a survey of gas plants made by the committee (FM.9) were completed in 1956. Work then outstanding was concerned mainly with the possibility of a local low-temperature (Linde) stress-relieving treatment of welded gas mains. Residual stresses caused by welding were shown to be the cause of the cracks which started in the heat-affected zone and not in the weld. The effectiveness of mild stress relief (450°C. to 500°C. for one hour) in preventing this stress-corrosion cracking has now been established, and a main at Oldham, stress relieved in this way, after eight years' service showed no sign of grain boundary attack. The mild stress relief lowers the residual stresses to a safe level.

Cracking of alloy steel weld metal Investigations on the conditions for cracking of alloy steel weld metals have recently been completed, under a contract from the Ministry of Supply, with the aim of specifying conditions which would ensure freedom from cracks. The cracking experienced in weld metal can be divided into two types, namely, hot cracking, which occurs at temperatures between 1,000°C. and the solidus, and cold cracking, which occurs at much lower temperatures, probably less than 200°C. From this work it was concluded that it was not practicable to specify a test for determining the liability to hot cracking of a given combination of electrode and parent plate.

As an alternative, it was proposed that limits should be specified for the composition of the weld metal. It was further noted that the conditions for hot cracking were not related to those for heat-affected zone cracking, and therefore conditions ensuring freedom from the latter would not necessarily guarantee that hot cracking would not occur. Similarly, with regard to cold cracking in the weld metal, it was found that it was not possible always to assume that conditions giving safety from heat-affected zone cracking would not lead to the formation of cold weld metal fissures. A simple test has been developed for assessing the tendency to produce fissures in cold weld metal.

Austenitic stainless steels For some years fissuring and hot cracking have been known to occur if fully austenitic weld metal is used for joints in austenitic stainless steel pipelines and pressure vessels. Special electrodes have therefore been used to deposit a weld metal containing a small and controlled amount of ferrite, but this has not always prevented these defects. Cracking also occurs in the heat-affected zone of heavy weldments. An investigation was started by the Association in November, 1957, when the committee first met, to investigate mainly 18% Cr-12% Ni-1% Nb steels, and to a lesser extent 25% Cr-20% Ni heat-resisting steels. Its purpose is to investigate the causes of cracking and fissuring both in austenitic parent metal and in austenitic weld metal. The literature has been surveyed, and apparatus is being prepared which is expected to show the temperature at which cracking occurs. This is the first step towards discovering the mechanism of the cracking and hence reliable methods of preventing it.

Non-ferrous research

High-strength heat-treatable aluminium alloys Several years ago the Association began investigating the difficulties of welding high-strength aluminium alloys of the Al-Cu-Mg type such as H 15, and of the Al-Zn-Mg type such as DTD 683. Both types have in the past suffered from weld cracking because suitable filler material has not been available. A satisfactory technique for welding them would be useful both in structural work and to replace forging or casting by welding, and in certain applications this is now possible. The director's report of 1955-56 mentioned a filler composition (7% Cu, 3% Si, 0·8% Mg) was found to be suitable for welding alloys of H 15 type. The properties of butt joints made with commercially prepared filler wire of this type on parent plate of low gas content have been comprehensively reviewed. Argon arc butt welds have been made in 12-gauge and in $\frac{1}{4}$-in. thick HS 15 WP and HC 15 WP alloys, and self-adjusting arc butt welds have been made in the same materials in $\frac{1}{4}$-in. and $\frac{3}{8}$-in. thicknesses. Further work has been carried out on filler materials for welding Al-Zn-Mg alloys of DTD 683 type, using compositions similar to the parent metal, but with additions of silicon.

Copper Three aspects of the gas-shielded arc welding of copper are being investigated: the argon-arc welding of thin gauge deoxidized copper without filler alloy, the

problems in welding tough-pitch high-conductivity copper, and the transfer of metal in gas-shielded metal-arc welding. Porosity in argon-arc welded 18 s.w.g. phosphorus-deoxidized copper is due to insufficient residual deoxidant in the parent metal for deoxidizing the weld pool, and for this reason filler metals contain powerful deoxidants. The effects of process conditions, paste fluxes and gaseous deoxidants are being investigated. The use of zinc-deoxidized copper (cap copper) as an alternative to phosphorus-deoxidized copper has been suggested, and preliminary results are encouraging. If the process were successful, welding could be used for the economical manufacture of water tanks and heat exchangers.

Titanium alloys Titanium is potentially a most useful metal in spite of its high price, because it has high corrosion resistance and low density (4·5 compared with 7·8 for steel). The yield point of the commercially pure metal is 50% higher than mild steel, though its Young's modulus is only half that of steel. The Association's main investigations are into (1) the metallurgical and mechanical properties of fusion welds in commercial alloys, (2) the design of manual nozzles for making uncontaminated welds in air using the self-adjusting arc and tungsten arc processes, and (3) the effect of oxygen and nitrogen on weld properties. A chamber has been designed and built at Abington for making welds without contamination in high purity argon, and in atmospheres containing deliberate additions of oxygen and nitrogen. This experience allows estimates to be made of the levels of contamination that can be tolerated and also enables the properties of welds made in air to be assessed with some certainty. The effects of nozzle diameter, nozzle-to-work distance and argon flow rate on gas coverage have been investigated for round nozzles, and the information gained has been used to design a compact nozzle for making welds free from contamination, in sheet thicknesses up to 14 s.w.g.

The mechanical properties of butt welds in commercially pure titanium (I.C.I.-130) in the alpha alloy Ti-5% Al-2½% Sn and in the alpha/beta alloy Ti-6% Al-4% V have been determined. High joint-strength efficiencies (85-100%) were obtained for all three materials, whilst the ductility of unalloyed titanium welds was about 75% that of the parent sheet, the alpha alloy reaching 50-87% and the alpha/beta alloy 41-82%. A micro vacuum-fusion gas analysis unit has been built for estimating oxygen and nitrogen in titanium and zirconium.

Zirconium alloys The second reactive metal now being studied is zirconium which, because of its low neutron absorption and excellent corrosion resistance in water at 325°C., is useful for nuclear power generation. Work now under way includes an investigation into the effect of welding variables on the corrosion of fusion welds in Zircaloy 2 and into the welding of Zircaloy 2 plate in thicknesses up to ½ in. by the self-adjusting arc and tungsten arc processes. Normally, fusion welds are made in a closed chamber containing high-purity argon, but to assess the effects of surface contamination on corrosion resistance some welds are made in air using specially designed nozzles. Equipment designed to measure accurately the welding variables has been made for the programme on the self-adjusting arc.

Cold pressure welding Investigations at Durham University, continuing earlier work on cold pressure welding, also sponsored by the Association, have shown in the past year that annealing increases the strength of cold pressure welds in copper and S.A.P. sheet and lowers their strength in pure aluminium sheet. The three materials were super purity aluminium, oxygen-free high-conductivity copper and S.A.P. sheet cold-rolled to strip 0·05-0·10 in. thick. Before the strips were welded, they were pickled, dried, degreased and scratch-brushed. Immediately after scratch-brushing two strips were welded together by rolling, giving decreases in thickness of 40-70% for aluminium and S.A.P. sheet and 60-80% for copper. The examination of welded specimens heat-treated for periods of up to 500 h. at 600°C. showed that the strengthening of copper and S.A.P. welds was probably due to recrystallization across the interface at any metal-to-metal contact.

Engineering research

Effect of defects in mild steel butt welds There has been no ordered research in Britain into the influence of defects in welds, and the Association has been making, since 1952, the first comprehensive British attempt to investigate the fatigue strength of mild steel butt welds. Since cracks or lack of penetration seriously lower the fatigue strength of welds, all highly stressed welds containing them are rejected. Porosity and slag inclusions lower weld strength less seriously, and it is therefore less easy to decide whether they should be condemned. To determine their levels of acceptability, investigation of these defects is therefore the first priority.

A series of check tests has confirmed that the fatigue strength of good quality transverse butt welds is largely dominated by the shape of the weld reinforcement. In order to do this, manually and automatically welded joints with the external reinforcement either left on, or machined off, have been tested. These tests have shown that while there may be significant variations in the fatigue strength of joints made by different processes when tested 'as-welded,' the basic strength obtained when the reinforcement is removed by machining always reaches the strength of the unwelded mild steel plate. As a further check that this general result is attributable to the shape of the discontinuity at the edge of the weld reinforcement, tests were also carried out on two automatically welded joints in which an attempt was made to improve upon initially determined strength values of 7 and 8 tons/sq.in. at 2,000,000 cycles by controlling the shape of the reinforcement, but still testing in the 'as-welded' condition. From these experiments the corresponding strength values obtained were 11 and 10 tons/sq.in., representing absolute values equivalent to the best performance of manually welded joints, and increases of 57% and 25% respectively. Evidence has also been collected on the influence of stress-relieving (650°C. treatment) the specimens before fatigue testing. In this case tests were carried out on four groups of specimens which were directly comparable, except for the stress relieving of two of the groups. For these specimens the 650°C. treatment in no way modified fatigue strength.

Shafts reclaimed by welding Highly stressed shafts repaired by metal-arc welding are unlikely to recover their original strengths even if great care is taken, using pre-heating, post-heating and a correct electrode. The fatigue behaviour of reclaimed ferritic steel shafts is therefore being investigated so as to define optimum reclamation procedures for dynamically stressed shafts. The approach, initially, has been to carry out fatigue tests on 2-in. dia. mild steel shafts by means of a resonance technique giving a stress system similar to that obtained in rotating bending. The shaft specimens contain a zone reclaimed by metal-arc welding, the surface deposit being machined. The welding variables included pre-heating and post-heating (stress relieving and normalizing).

In order to make the fullest use of available shaft

continued on page 36

Steel castings research

In accordance with usual practice the Fifth Annual Report (1958) *of the British Steel Castings Association contains a section reviewing progress in current research. This covers steelmaking, foundry processes and moulding materials, metallurgy and industrial health. The following extracts are taken from the report*

Oxygen injection in basic arc furnaces The programme of work to assess the effect of the variables: initial carbon level, metalloid content, temperature, injection rate, slag composition, etc., previously carried out in member foundries is now being carried out in the Association's graphite resistor rod furnace under conditions of more stringent control than was possible in production furnaces. Over 100 heats of steel have been made at the research station during the past year. A comparison of results between production furnaces and the Association's furnace has shown that the values of oxygen utilization measured in terms of points of carbon removed per cubic foot of oxygen per ton of steel and the overall efficiency measured in terms of ' cumulative potential ' were equally applicable in all cases. There is thus no scale effect to be considered in the application of the data obtained in the resistor rod furnace to production furnaces.

The carbon control chart previously constructed from the oxygen survey made in member foundries has now been reconstructed on the basis of the more accurate data obtained from the resitor rod furnace. This chart is applicable to a bath temperature of 1,600°C. prior to the injection of oxygen. The scope of the chart is being extended to take account of different initial temperature levels and the effect of the silicon and manganese content of the bath at the commencement of oxygen injection. This work is being combined with a quantitative study of the relationship between fume evolution and the conditions of oxygen injection.

Shell moulding A comprehensive investigation has been made of the effect of various resins, moulding materials and inorganic additives on the surface quality of shell moulded low-carbon steel castings, which frequently show a defective surface finish when cast in normal silica sand-resin mixtures. The test casting used for this work incorporated sections of ¼ in., ½ in. and 1 in. thickness. Ten different resins were tested, but all produced defective surfaces. Additions of manganese dioxide, calcium carbonate and lead dioxide, which have been claimed to produce improvement, were relatively ineffective except in the thinner casting sections where a slight improvement was noted. Resin-bonded zircon sand with an addition of manganese dioxide produced a definite improvement in surface quality, but the best results were obtained with resin-bonded olivine sand with or without an addition of manganese dioxide.

The use of inorganic instead of resin binders has also been investigated. Thermally-hardened sodium-silicate bonded shells had adequate strength and produced defect-free castings, but a considerable amount of mould distortion occurred on thicker sections due to the rapid softening and melting of the silicate bond when molten steel entered the mould. The use of aluminium phosphate as a bond was also explored, but was rejected due to the large amounts required to produce a sufficiently strong shell.

Measurements of the carbon pick-up at the surface of austenitic steel castings in resin-bonded silica sand shell moulds showed that this was reduced by approximately 50% by an addition to the sand of manganese dioxide.

Microporosity in steel castings The object of this work has been to discover to what extent finely dispersed microporosity in steel castings was due to micro-shrinkage and to what extent it was due to the evolution of gas, both occurring in the last stages of solidification. An examination has been made of several keel block castings made from air melted carbon steel in comparison with castings of the same composition cast at the same temperature and into the same type of mould but melted in pure hydrogen, thoroughly degassed and poured under a low pressure of argon.

The incidence of microporosity was determined by semi-microradiography of thin slices cut from the castings and by measurements of density and ductility of miniature tensile test pieces cut from suitable locations in the casting. Although the average density of the vacuum degassed steel was consistently higher than that of the air-melted steels, the tensile ductility of the vacuum-treated steel was only very slightly higher on average than that of the air-melted steel. Semi-microradiography has revealed that even the vacuum-treated steel castings are not free from microporosity and it has been concluded from this work that micro-shrinkage exercises a greater influence on the incidence of microporosity than does gas evolution. For this reason work on this project has been re-orientated and a closer study will be made of the effect of feeding during solidification on the incidence of microporosity.

Magnetic properties of cast steel Measurements have been made of the effects of small quantities of nickel, chromium, molybdenum, copper, tin, and lead, and larger quantities of manganese on the magnetic properties of cast 0·1% carbon steel. In general, the addition of all these elements, except copper, impairs the magnetic properties. Copper in quantities up to 0·35% has virtually no effect. Some evidence has been obtained that the gas content may have a significant effect on the magnetic properties and a further investigation is in hand on this point. The effect of small quantities of carbide-forming elements, *e.g.* titanium and zirconium, is also under examination.

Progress in welding research

concluded from page 35

material with a known mill history, composite specimens are being made up. These consist of 5½-ft. lengths of shaft in which the middle third is the test material, the two outer lengths being joined by flash welding. The method of depositing the surface layer of weld metal in the zone to be reclaimed is based on the open spiral technique which is known to keep distortion to a minimum. To overcome the difficulty of maintaining a uniform pitch in the spiral, a simple mechanism has been devised to provide the correct speed of electrode traverse while the shaft is rotated.

Nozzles in pressure vessels Steadily advancing boiler and vessel operating conditions, and the demands of the nuclear power industry, are forcing boilermakers to build for higher pressures, temperatures and capacities than were previously thought possible. The disadvantages inherent in the making of thick steel plate, the desire to achieve economies by using higher stress conditions and the risks from possible failure, combine to give a high priority to the Association's work on pressure vessels.

NEWS

Future trends in welding

THE FUTURE EXPANSION of the welding industry was discussed by Mr. John Strong, Chief Executive Director of British Oxygen Gases Ltd., in his presidential address to the Institute of Welding recently.

Mr. Strong said that a very wide range of arc-welding processes were already available to industry, some having been evolved quite independently of each other. If welding was to expand, must there be new editions to this wide range or could an amalgamation of some or all of the processes now be achieved?

This aspect of welding development had been given much attention in recent years and he believed the time was coming when there could and would be considerable simplification. Examples of what had already been done lay in the use of CO_2 shielding with an automatic flux-covered electrode, the use of gas shielding with magnetic flux, and the automatic flux-covered electrode working under a fused submerged arc flux.

This tendency needed to be pressed home. Perhaps, in time, instead of a dozen processes each possessing individual advantages over the others, we would have three or four. This would at once permit further rationalization of automatic welding-head designs and a greater standardization of electrical power supply equipment. It was possible to see this coming now in the automatic and semi-automatic welding heads which would cater for four or more of the current processes, and a similar trend was appearing in the various forms of electric power supply. Handling gear, including jigs and manipulators, was being steadily rationalized and standardized in design while covering a wider field than ever before.

In automatic welding also, Mr. Strong considered that we would see more and more of the complete welding installation and the complete machine. It was possible that equipment would become more intricate in itself in order to have a more universal and simplified application.

The scientists of the future might find a totally new way of imparting welding heat, perhaps through the direct application of nuclear energy. We were not concerned with this aspect at the present time, however, and had now reached a stage, no doubt a temporary one, when consolidation was perhaps the most important factor to be borne in mind.

Wild-Barfield furnaces for Holland

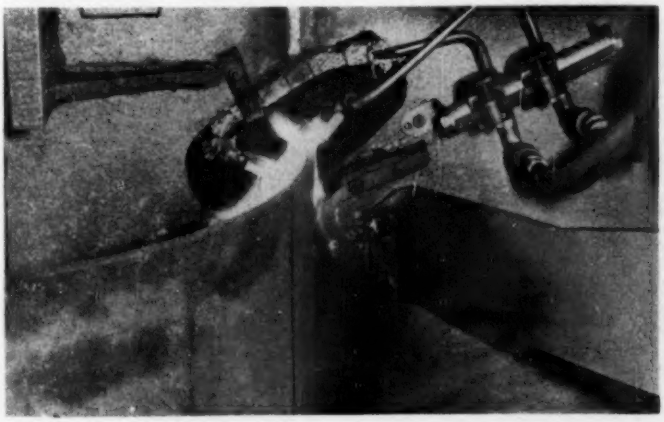
For production gas carburizing and carbonitriding of components, the heat-treatment department of Van Doorne's Automobielfabriek N.V. ordered three gas carburizing furnaces to supplement those already supplied and a large shaker hearth equipment from Wild-Barfield Electric Furnaces Ltd., of Watford. Recently the equipment left Elecfurn Works for Eindhoven, where it will join other Wild-Barfield furnaces at the DAF Works.

Flame descaling in tube production

The tube works of Stewarts & Lloyds Ltd at Coatbridge was recently faced with the problem of removing mill-scale before the seam-welding of steel tube could be carried out. The importance of cleanliness in the weld meant that a descaling operation had to be introduced. British Oxygen Gases Ltd supplied special flame cleaning equipment which was fitted to the slitter beam of the tube forming and welding machine. This equipment comprises a 2-in. flat nozzle directed on the outside of the tube and a 3-in. flat nozzle directed on the inside.

Driven by friction rolls, the tube, already shaped for welding, passes at a constant speed through the machine. A pair of edge-forming rolls 'tighten' the shape of the tube which then passes between the two descaling heads. These are poised so that both sides of the open seam, along which the welding takes place, are subjected to sudden intense heat. This causes fairly violent differential expansion and contraction over an area of ½ in. on each side of the plate, thus cracking off the heavy scale. The tube then moves on between two further pairs of friction-driven rolls and a mechanically-driven wire brush ensures the removal of all final traces of scale. The tube then enters the welding zone of the machine where the edges are fused by the submerged arc process.

This method has proved reliable and simple to operate, and the equipment was rapidly installed at a fraction of the cost of shot-blasting equipment. Tubes up to 27 ft in length, 18-50 in. dia and ¼-⅜-in. wall thickness can be dealt with.



Close-up of the flame descaling process with a tube just beginning the descaling run. The pipes feeding the nozzles are made of Monel and the lower one is asbestos covered. The tube moves from left to right

Europe's first beryllium plant

Imperial Chemical Industries Ltd, Metals Division, is to establish the first plant in Europe for the production of wrought beryllium. The plant is designed to produce semi-fabricated forms of the metal, such as rod, tube and plate, and finished machined parts. Its first task will be the execution of a production scale contract placed with I C I by the U K Atomic Energy Authority (Industrial Group) as part of a nuclear development project. Subsequent spare capacity may find additional outlets for this unusual metal, as for example in the aircraft industry.

Interest in beryllium as a nuclear engineering material has been intensified by the need for a metal which will perform satisfactorily in the higher operating temperatures envisaged in gas-cooled reactors. For the present programme of British reactors, operating at temperatures up to about 470°C, special magnesium alloy materials are used for sheathing the nuclear fuel. For the higher temperatures needed to obtain increased thermal efficiency, materials with greater strength at these temperatures must be used and the most promising of these is beryllium.

This metal, which has a melting point of 1,280°C, is light in weight, has good mechanical properties and good corrosion resistance to carbon dioxide at elevated temperatures. In addition, beryllium has by far the lowest neutron absorption cross-section of any of the possible constructional metals. For this reason the Industrial Group, U K A E A, intends to use beryllium fuel cans in its advanced gas-cooled reactor, in which fuel element surface temperatures as high as 600°C are planned.

The handling and fabrication of beryllium involve specialized techniques to overcome difficulties arising from its particular metallurgical characteristics and from the toxic properties of the metal in certain compounds and forms. Thanks to considerable research which has been carried out into the safe handling of beryllium products by the U K A E A, stringent standards of operation have been evolved and codified, and the I C I plant will incorporate all the special features which have been found necessary for this purpose.

Some unusual features are involved in the manufacture of wrought forms of beryllium. The metal, which is received as flake or as small beads, is melted under vacuum in induction furnaces to produce an ingot. This is really a refining process: the cast ingot, having a large grain size and very poor workability, cannot be rolled or extruded directly in the same way as conventional metals are. It has to be made into fine powder which is then heated and compacted ('sintered') under vacuum to produce the various shapes required for further processing by conventional plant.

Nuclear engineering

I C I has been entrusted with this task following its already considerable contributions to the development of nuclear metallurgy. In the very early days it solved problems connected with the extrusion of uranium and undertook the production of porous barriers for diffusion membranes in uranium isotope separation plant.

Much of the early work in devising suitable forms of sheathing (or 'canning') for nuclear fuels was done by the Metals Division in conjunction with the Authority. I C I aluminium cans are in use in many of the experimental reactors at Harwell and elsewhere, and the Division has manufactured and supplied prototype cans in magnesium and zirconium alloys to all the consortia in this country and to official bodies abroad.

The Metals Division has for many years undertaken special research and development on the 'new' metals. Titanium and zirconium have already left this class and are in commercial production. Work is still proceeding on other metals, including vanadium, tantalum, niobium and beryllium, the last of which is now planned to be in production at the end of next year.

Other possible uses for beryllium

The potential uses of beryllium are not confined entirely to the field of nuclear engineering, and there is considerable long-term interest in the metal among aircraft and missile designers. Its very low density and high tensile strength make it a promising material for aircraft skinning. It is, in fact, reported that beryllium is being used in this way in North American Aviation's latest research aircraft X-15, designed to fly at speeds up to Mach 7. From the viewpoint of the engineering designer, the metal's most attractive property is its high strength/weight ratio; it has a density little more than half that of aluminium and a stiffness four times as great.

The forging of steel

The Wolverhampton and Staffordshire College of Technology, Department of Applied Science, is holding the fourth annual iron and steel reviews on the subject of 'the forging of steel.'

Details of the proposed course are as follows:

February 10. Review of forging process: systematic outline of present and future trends, G. H. Jackson (NADFS).

February 17. The production and examination of forging ingots, W. Ash (Steel Peech & Tozer Ltd.).

February 24. Rapid heating of forging stock, E. May, College of Technology, Birmingham.

March 3. Technique of heavy forging, F. C. Bird (Walter Somers Ltd.).

March 10. Drop-forging technique, A. Hughes, (T. B. Wellings & Co. Ltd.).

April 7. Press-forging and upsetting, R. E. Winch (Garringtons Ltd.).

April 14. Developments in die sinking, W. E. Golcher (John Golcher Ltd.).

April 21. Die steels, E. Johnson (William Jessop & Sons Ltd.).

April 28. Control of quality, H. Southam (A. J. Vaughan & Co. Ltd.).

Electrical industrial data sheets

As part of its campaign to encourage the extended use of electricity by industry, the Electrical Development Association is running a series of page advertisements headed 'Electrical aids in industry.' These take the form of illustrated data sheets, each outlining a particular application of electricity, and stressing the advantages resulting from its use. The sheets are marked for perforation by a punch so that they can be removed and kept together in a folder. Those issued or in course of preparation up to the present are entitled: Electro-heat, Induction heating 1 and 2, Resistance heating 1 and 2, Light-sensitive cells, and Industrial lighting. Others will follow from time to time covering such subjects as electronics and automation.

Copies of the data sheets can be obtained after publication as advertisements on application to the Electrical Development Association at 2 Savoy Hill, London, W.C.2.

Metropolitan-Vickers London offices

The offices formerly located at 1-3 St. Paul's Churchyard, London, E.C.4, have removed to 33 Grosvenor Place, London, S.W.1 (BELgravia 7011).

PEOPLE

Mr. F. Cousans

Mr. G. Wood

Mr. R. C. Heys

THE FOLLOWING APPOINTMENTS to the board of Hadfields Ltd., East Hecla Works, Sheffield, have been announced: **Mr. Fred Cousans,** F.I.M., was educated at the City School, Lincoln. On leaving at 18 years of age he joined Babcock & Wilcox and served as technical apprentice for a period of four years before commencing with Firth Brown at Scunthorpe as technical assistant. Promoted works manager prior to leaving and started with Catton & Co. Ltd. in a similar capacity during 1944. In 1947 he joined Hadfields Ltd. as foundry superintendent and was appointed local director in the same year.

During latter years Mr. Cousans has presented papers to various technical institutes, including the I.B.F. and A.F.A. He is an active member of the B.S.C.R.A. Research Committee and chairman of the Foundry Production Committee, Sheffield branch. Mr. Cousans is also president of the I.B.F. Sheffield branch.

Mr. George Wood, A.MET., A.I.M., joined Hadfields Ltd. in 1935 as metallurgist, Research Department, and was promoted assistant research manager in 1945. He was engaged on special armament work during war years and was closely associated with special Government activities.

During 1949 he took up duties on the production side of the organization and in 1950 was appointed heat-treatment superintendent and local director in 1956. Mr. Wood is a native of Sheffield and was educated at the Sheffield Central Secondary School. He left at the age of 17 years and joined the Research Department of English Steel Corporation. He gained his Associateship in Metallurgy at Sheffield University in 1935.

Mr. R. C. Heys, the present managing director of Millspaugh Ltd., a subsidiary company of Hadfields Ltd., has also been appointed to the board.

Sir John Wrightson, Bt., chairman of Head Wrightson & Co. Ltd., Thornaby-on-Tees, was elected to the council of the Industrial Welfare Society at the last annual meeting in London.

After leaving Eton he worked for Alfred Herbert Ltd., Coventry, James Archdale & Co. Ltd. and H. W. Ward & Co. Ltd., Birmingham, before spending a year with Head Wrightson & Co. South Africa (Pty.) Ltd. He joined the company in England on his return from South Africa.

Sir John is honorary treasurer of the Smeatonian Society of Civil Engineers and has been connected with the society for more than 20 years. He is also a member of the Tees Conservancy Commission.

On his recent return to this country the building engineer of the Copper Development Association, **Dr. E. Carr,** PH.D., B.SC., C.G.I.A., had completed an itinerary involving large areas of Northern and Southern Rhodesia together with several places in the Union of South Africa.

The primary object of Dr. Carr's visit was to investigate the use of copper for building purposes within these localities. Whilst obtaining a comprehensive appreciation of prevailing African conditions, Dr. Carr was at the same time able to advise architects, local authorities, builders, plumbers and fabricators on many subjects appertaining to the employment of this metal.

To meet the shortage of skilled labour generally prevailing throughout Africa a new type of prefabricated copper roofing has been developed by the C.D.A. Building Department during the last 12 months. This aroused considerable interest and was discussed with architects, public works department officials, and contractors.

Though the services available at the C.D.A. headquarters in London have always extended to all parts of the Commonwealth, it has now been decided to form an independent C.D.A. in this area in order to further the use of copper and its alloys by African industries. During the course of his tour Dr. Carr was able to assist and advise on the establishment of such an organization.

Mr. Lewis Chapman, C.B.E., succeeds Sir Andrew McCance, F.R.S., as president of the British Iron and Steel Federation for 1959.

Mr. Chapman, chairman of William Jessop & Sons Ltd., has been connected with the B.S.A. group of companies for many years. From 1905 he has had experience in both the production and commercial sides of the steel business, and was in 1931 appointed managing director of both William Jessop & Sons Ltd. and J. J. Saville & Co. Ltd. Mr. Chapman held these two positions until 1955, when he was elected chairman of these two companies forming the steel interests of the B.S.A. group.

In 1935 Mr. Chapman was appointed to the council of the British Iron and Steel Federation, and since the end of the war he has been a member of the executive com-

mittee and has also served on a number of other Federation committees.

Mr. Chapman was the chairman of the Crucible and High-Speed Steel Conference from 1945 to 1957. He was also the chairman of the High-Speed Steel Association and of the Stainless Steel Manufacturers' Association for a number of years.

The award of C.B.E. was conferred on Mr. Chapman in the New Year Honours in 1955. He holds the following directorships: Birmingham Small Arms Co. Ltd., William Jessop & Sons Ltd. (chairman), Birtley Engineering Ltd. (chairman), J. J. Saville & Co. Ltd. (chairman), and High-Speed Steel Alloys Ltd. (chairman).

Latest appointment to the board of the English Steel Corporation Ltd., Sheffield, that of **Mr. W. E. A. Redfearn,** took effect in the New Year. The new director has been associated with English Steel and its predecessors since 1915.

During the last war he was a member of Lord Beaverbrook's aircraft steel drop-forging committee and the Drop Forgings Advisory Committee of the Ministry of Supply. From 1944 to 1949 Mr. Redfearn was chairman

Mr. W. E. A. Redfearn

of the Heavy Steel Castings Association, and in 1951 was elected chairman of the Alloy Steels Association. A past president of the National Association of Drop Forgers and Stampers, he is also chairman of the Forging Ingot Makers' Association. He also serves the industry as a member of the council of the British Iron and Steel Federation.

Mr. Redfearn joined the forge department of Vickers Ltd. in Sheffield in 1915, and transferred to the sales department five years later. For a number of years before his appointment as special director he was acting sales manager. He is assistant managing director of the English Steel Forge & Engineering Corporation Ltd. (and will become deputy managing director on January 1), and a director of the English Steel Rolling Mills Corporation Ltd.

Mr. Richard F. Summers has been appointed president-elect of the British Iron and Steel Federation for 1959.

Mr. Summers, chairman of John Summers & Sons Ltd., is a grandson of the founder of the firm. He entered the family business in 1925 and was appointed a director in 1931. In 1936 he became managing director. Mr. Summers visited the United States in 1937 to study the continuous method of hot and cold rolling of sheets, and on his return recommended that the company should change to continuous rolling in place of the old handmills. His recommendation was unanimously accepted. In 1939 Mr. R. F. Summers became chairman of the company in place of his father, who was appointed president.

When the British Iron and Steel Federation was formed in 1934-35, Mr Summers was appointed to both the council and the executive committee, and he has served on a number of other Federation committees. He is at present chairman of the Public Relations Committee, and a member of the Price Policy, Steel Production and Supplies, Development and Accident Prevention Committees. Mr. Summers has been chairman of the Sheet Makers' Conference since 1945, and in the same year was elected a member of the Iron and Steel Institute.

From 1943 until the nationalization of the railways Mr. Summers was a director of the London, Midland and Scottish Railway, and he is now a member of the Midland Area Board of the British Transport Commission. Mr. Summers is also on the boards of the following concerns: District Bank Ltd., Liverpool and London and Globe Insurance Co. Ltd., Royal Insurance Co. Ltd., the United Steel Companies Ltd., and the Steetley Co. Ltd.

Mr. William Barr, O.B.E., honorary treasurer since 1953, has been nominated by the council for election as president of the Iron and Steel Institute for the 1959-60 session. He will take office at the annual general meeting on May 6.

William Barr was born at Larkhall, Lanarkshire, and educated at Hamilton Academy and the Royal Technical College, Glasgow. He joined David Colville & Sons Ltd. in 1922 as a metallurgist, becoming assistant works metallurgist at Dalzell Works in the following year. He became chief metallurgist of Colvilles Ltd. on the formation of the company in 1936. He was appointed a director of the Fullwood Foundry Co. Ltd. in 1945, and executive director of Collvilles Ltd. two years later; he became a full director of the company in 1954.

Mr. Barr is the author of many technical papers, and has served on numerous official and industrial committees. Of special note was his connection with the International Institute of Welding; he served as British delegate on Commission XII (Brittle Fracture) from 1948 until it was merged with Commission IX (Weldability) in 1954, and served on the new joint Commission IX (Behaviour of Metals subjected to Welding) until this year. His research activities have been devoted to investigations on creep, brittle fracture of mild steel, and the development of low-alloy high-tensile structural steels and stainless-clad steels. He is a Founder Fellow and past president of the Institution of Metallurgists, and a past president of the West Scotland Iron and Steel Institute. He joined the Iron and Steel Institute in 1925, becoming a member of council in 1948 and honorary treasurer in 1953.

Mr. R. H. Mardell

Mr. R. H. Mardell has been appointed London area sales manager for General Refractories Ltd. in succession to Mr. T. S. Aikman who has recently retired. Mr. Mardell has been assisting Mr. Aikman for several years as London area sales representative.

BOOKS

The metallurgy of vanadium

By W. Rostoker. John Wiley & Sons Inc. £3 8*s.* net.

THIS BOOK is very similar to a number of books which have been appearing regularly in the last few years, namely, books describing the extraction, properties and alloys of one of the so-called 'newer' metals. It takes its place as a satisfactory member and should be obtained as a reference book by all metallurgical libraries which are likely to be interested in vanadium. It will also be very useful to any metallurgist starting work on vanadium, since it will save him a great deal of chasing references to previous work. It follows the pattern of most of its predecessors and starts with a chapter on extraction, and follows this with chapters on physical properties of alloys, mechanical properties of the metal and its alloys, technology, *i.e.* methods of casting, rolling, etc., oxidation, corrosion, metallography and vanadium as an alloy addition.

British metallurgists will be delighted to find that all temperatures are in degrees centigrade.

The book very competently does what it sets out to do, but it is not interesting to read. This may be due to the fact that to date vanadium, alloyed or unalloyed, has no industrial use except as a minor alloying addition.

J. H. RENDALL

Effects of radiation on materials

Edited by J. J. Harwood, Henry H. Hausner, J. G. Morse and W. G. Rauch. Chapman & Hall Ltd. £4 4*s.* net.

THE FOREWORD of this book explains its purpose. 'Until relatively recently, much of the information concerning the effects of radiation upon materials was not readily available to the scientific and engineering community. The 1955 Geneva Conference on the Peaceful Uses of Atomic Energy provided the impetus for the release of a large body of information by the U.S. Atomic Energy Commission and foreign sources. As civilian usage of nuclear power expands, so will the necessity increase for engineers and scientists to become familiar with this fascinating subject. A start in this direction was made at a colloquium on "The Effects of Radiation on Materials . . . at Johns Hopkins University in Baltimore in March, 1957. Its purpose was to present a series of unclassified reviews that were educational in nature and gave a broad coverage to this field. . . . These papers deal with metals, alloys, inorganic dielectrics, semi-conductors, organic and polymeric materials and materials for nuclear reactor components including fuel elements, moderators, coolants and shielding materials. Theories and concepts of radiation effects, radiation sources and measurements of radiation and the known effects of radiation on the physical, metallurgical, mechanical, corrosion and electrical properties are presented. In addition, there is discussion of the current thinking on the behaviour of organic materials, including the effects of radiation upon polymeric reaction processes, *e.g.* graft copolymerization." '

It will be seen that this is a very broad field to cover in educational lectures and in a book of 350 pages based on them. The result is a very concentrated course and the book is anything but light reading. The first sentence refers to 33 items, mostly Geneva Conference papers but including two books.

Nevertheless, the authors of the various chapters and the editors have succeeded in what they set out to do, and the book is a very useful introduction for those who feel they ought to be familiar with the effects of radiation damage, *i.e.* all metallurgists and most other engineers and scientists.

Each chapter concludes with a list of 50 to 120 further references and the book ends with a bibliography of 779 —owing to the conciseness of the book serious readers will find themselves obliged to consult a great many of these.

The book is well produced except that a few diagrams have been so reduced in reproduction that they are difficult to understand. The extensive use of jargon and initials, *e.g.* scram and LMFR, in certain chapters, is probably unavoidable.

J. H. RENDALL

Trouble-free hydraulics

By Ian McNeil. Thames & Hudson Ltd. London, 1958. 18*s.* net.

THE SUBJECT-MATTER in this book makes interesting reading and constitutes a most useful manual for the servicing and maintenance of hydraulic machinery. To students and engineers concerned more with the theory and application of hydraulics it forms a useful guide to the practical aspects of hydraulics.

In this age and in the years ahead when hydraulics will be required to contribute more and more to automation, the need for such a book is obvious. To have at hand in a concise and comprehensive form the 'do's and don'ts,' checking methods, and servicing of hydraulic machinery to which reference can be made, will be one of the most useful aids to maintenance personnel can have.

The book contains information set out in a most convenient form with fault-finding charts, maintenance and servicing schedules, and can be likened to motor-car manuals where information and servicing requirements are tabulated for quick and easy reference. An easily-read index enhances the use of the book.

There can be little doubt that this handbook will go a long way to filling the need for a practical manual and guide to assist in getting to terms with oil hydraulic equipment to obtain reliability and confidence in operation.

D. C. BARNES

Welding aluminium

Since Northern Aluminium Co. Ltd. first issued the book 'Welding aluminium' some three and a half years ago, when the methods available for welding light alloys were not very widely known nor the characteristics of aluminium-welded joints fully appreciated, great advances have been made both in technique and the amount and scope of work done.

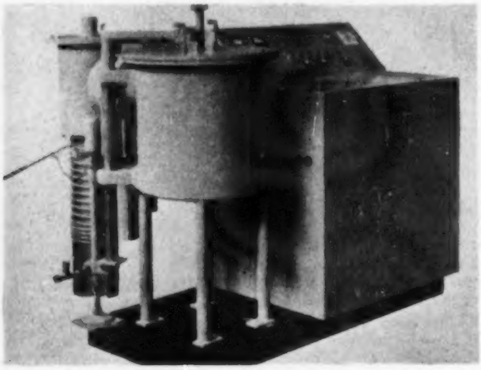
An extensively revised edition of the book has for some time been considered necessary and has now been produced. As before, it deals almost exclusively with the two shrouded arc processes—'argon tungsten arc' and 'inert metal arc'—and much of the space is taken up with tables of procedures. However, the information on processes has been brought up to date, a section has been added on welding technique, and the tables of procedures have been entirely revised, with full explanatory notes and illustrations giving edge preparation and joint details. In addition, an appendix has been added giving information on alloys and current ratings.

NEW PLANT

High-temperature vacuum furnace

A new cold-wall resistance-heated vacuum furnace capable of operating at temperatures up to 2,200°C. has been recently developed by F. J. Stokes Corporation, 5500 Tabor Road, Philadelphia 20, Pa. The unit is suitable for sintering powder metal parts compacted of materials with a very high melting point, such as tantalum, or for degassing components such as tungsten elements for electronic tubes, which require equally high temperatures, as well as for other heat-treating operations, either in experimental work or small-scale production.

The furnace is a compact unit, of approximately desk-top height, 5 ft. 4 in. long and 4½ ft. wide. Within the vacuum retort, which is 20 in. dia. and 20 in. deep, is a hot zone 3½ in. dia., and 6½ in. deep, produced by a



1 *Resistance-heated vacuum furnace*

resistance-heated radiant cylinder. This hot zone is surrounded by a water-jacket. Hot zones of varying sizes can be interchanged within the retort, to handle workpieces of different dimensions and types.

Gas sampling

Accurate knowledge of the quantities of industrial fumes and dusts discharged into the air is fast becoming a 'must' for management. Legislation governing some emissions is already in force and it is likely that official control will be steadily extended.

The problem is one which affects practically every industry and the iron and steel industry in particular. In consequence, the British Iron and Steel Research Association has developed a system of gas sampling and measuring which in a series of works trials has proved very successful.

Longworth Scientific Instrument Co. Ltd., Thames Street, Abingdon, Berks., has now developed a production version based on BISRA principles, 'LISA' (Longworth isokinetic sampling apparatus).

Primarily the system is a guide to grit, dust, and fume-emission dangers from the nuisance-value angle. Secondly it has considerable value as an aid to process control. By measuring the flow rates and temperatures of gases, it can indicate the presence of air leaks and consequent waste of heat and fuel. In steelmaking, quick and repeated measurements of dust and fume concentrations can yield valuable information on production technique. In sinter-making, knowledge of an increase in the grit content can give warning that the system is not working well and can save damage to the fans.

The main advantage lies in the speed with which samples can be taken. Careful design of the filter assembly ensures very rapid filter-changing—taking no more than about 10 sec.

The units comprising the complete apparatus are housed separately, with flexible connections; access to ducts and chimneys is often difficult and the ability to distribute the train of apparatus on ledges and steps increases considerably its range of application.

Pre-heating and stress-relieving of welds

The application of electrical resistance heating in the heat-treatment field, pioneered by Electrothermal Engineering Ltd., 270 Neville Road, London, E.7, in the form of armoured heaters, is being used by engineers for pre-heating and stress-relieving of welds and heat treatment generally.

Muffle furnaces, gas jets and induction coils are replaced with lengths of armoured heaters consisting of nickel-chrome resistance wires specially insulated to withstand working temperatures of up to 800°C. and covered overall with a flexible nickel alloy sheath, having an o.d. of $\frac{5}{16}$ in.

The heaters, which can be applied to curved or flat surfaces, are placed about the area to be heated, connected to an electrical supply and then covered with sections of high-temperature-resistant lagging. Armoured heaters operate at voltages of 50, 75 or 100, and a welding transformer, generator or a mains transformer can be used. The temperature is measured by a thermocouple or couples connected to a simple indicator, the readings from which enable the operator to control the temperature by on/off switching or voltage regulation. Other forms of temperature indicators, recorders and control gear can be supplied. A large amount of heat can be dissipated in the required area, for example an 18-ft. length at 75 volts is rated at 3 kW. All heaters are re-usable and are available in standard lengths according to the rating required.

2 *Armoured heaters for pre-heating and stress-relieving*

Electrical Aids in Industry — *Data Sheet* **No. 3**

Induction Heating – 2

The broad principles involved in the use of induction heating for melting and processing metals have already been dealt with in this series (Data Sheet No. 2). In order to make a critical examination of its possibilities, however, the potential user should be aware of certain technical factors which must influence his decisions.

Induction heating, of course, demands the use of alternating current which is available from the public supply at a frequency of 50 cycles per second. Higher frequencies, however, are desirable for certain applications and can be obtained by means of the appropriate conversion equipment. Frequencies can therefore be considered in three categories:

Mains Frequency
(direct from mains)—50 c.p.s.
Medium Frequency
(machine generator)—50–10,000 c.p.s.
High Frequency
(electronic generator)—up to about 2,000,000 c.p.s.

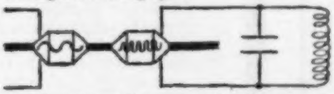
Mains Frequency

This needs no conversion equipment; it is particularly suitable for melting large pieces of scrap, and owing to the vigorous stirring forces produced, is excellent for alloy making. It has the merit of low initial cost compared with the high frequency method of melting, but is not so suitable for the production of high-grade steel.

A typical example of the use of mains frequency is the coreless induction melting furnace which can be connected direct to the public 3-phase supply. Such a furnace rated at 120 kW, with a holding capacity of 2,240 lb., will give a throughput of 5,000 lb. per hour of hot cupola metal superheated from 1,350°C to 1,450°C.

Medium Frequency

Motor generators ranging from 10 kW to 1,500 kW or more at frequencies up to about 10,000 c.p.s. are widely used for heating for forging, melting from 100 lb. to 10 tons, hardening, annealing, etc. A bank of capacitors maintains a high power factor during the heating cycle.



Another form of generator for frequencies of 1 to 2 kc.p.s. and powers around 250 kW, useful for forge heating and melting high temperature aircraft alloys, is a 6-anode steel tank mercury arc inverter.

High Frequency

Metal hardening and metallurgical processing are best handled by high frequency induction (up to about 2,000,000 c.p.s.), particularly when a very thin case is required or when the section of the workpiece is too small to heat satisfactorily at medium frequency. These high frequencies are produced either by an electronic h.f. generator or a mercury-gap h.f. generator.

The choice of frequency depends upon the metallurgical requirements and the size of the component to be treated. The following table gives the practical relationship between size and frequency, and may be used as a guide to the choice of generator, subject to metallurgical considerations.

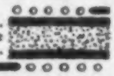
	Optimum Values			
FREQUENCY C.P.S.	3,000	10,000	500,000	2,000,000
MIN. DEPTH OF HARDNESS POSSIBLE	.060"	.040"	.020"	.010"
	Practical Values			
MIN. DEPTH HARDNESS EXPECTED	.150–.200"	.100–.150"	.030–.050"	.015–.030"
MIN. DIA. SURFACE HARDENING THIN CASE	2" & over	1" to 3"	½" to 2"	¼" to ½"
MIN. DIA. SURFACE HARDENING DEEP CASE	2" & over	2" & over	1" & over	not suitable
MIN. DIA. THROUGH HARDENING	1" & over	½" to 2"	¼" to ½"	not suitable

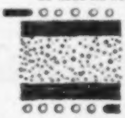
These are of course very approximate since they also depend on metallurgical considerations.

Power required for H.F. Induction Hardening

The high frequency power required per sq. in. of hardened surface depends upon the amount of metal behind the surface. Higher powers and shorter heating cycles are necessary for thin cases and when the thickness of metal behind the surface is small.

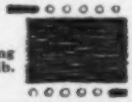
0.03" to 0.04" requires 1 sec. or less at 10 kW or more per sq. in.





0.1" to 0.2" with a large mass of metal behind the surface, requires 10–60 secs. at 2 kW per sq. in.

Through hardening requires 10–12 kWh per lb.



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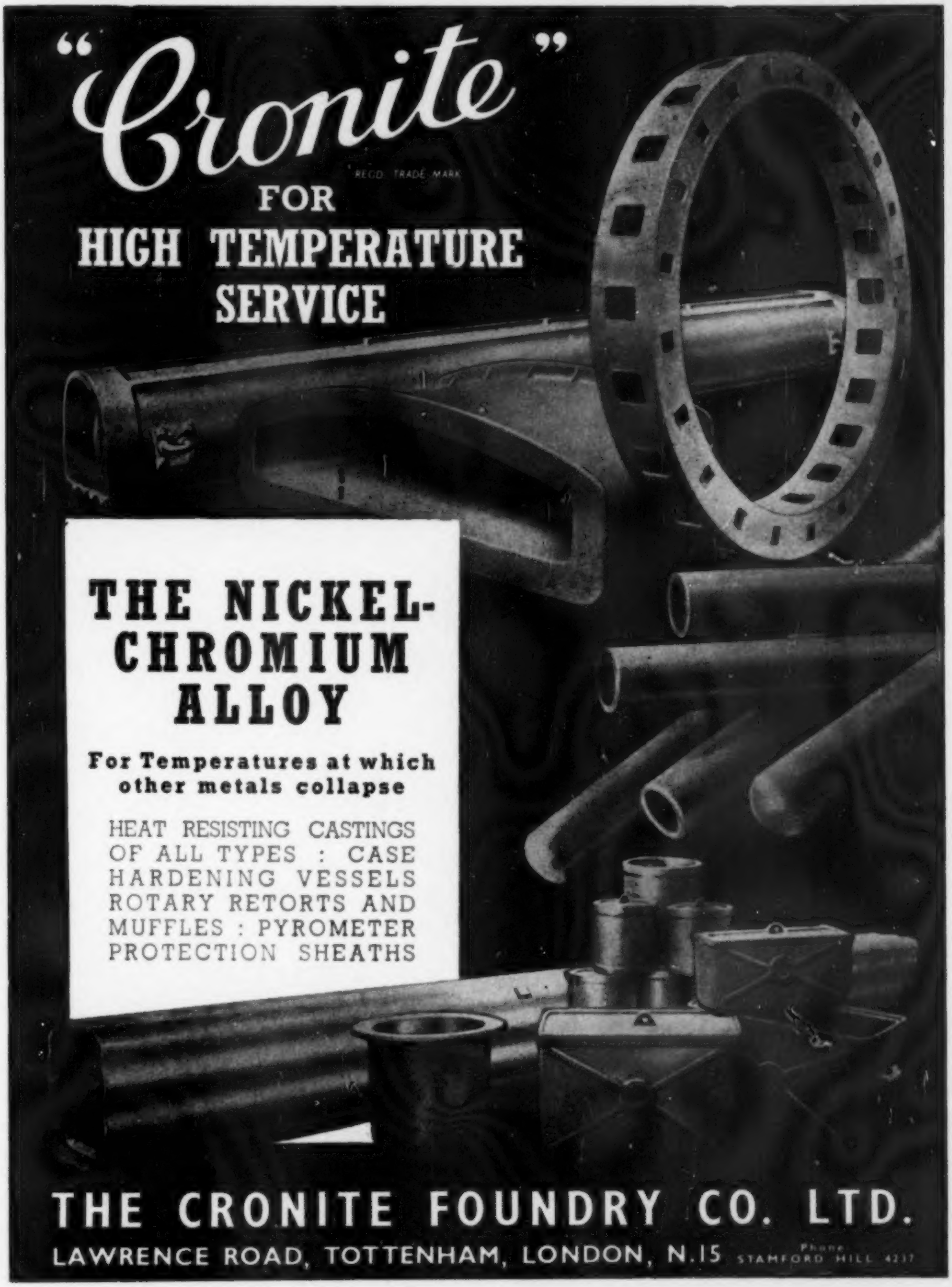
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